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This report deals with the energy and resource potentials of the USSR with emphasis on the present and future Siberian developments. An extensive discussion is included of what is presently existing in the Siberian industrial base and the proposed expansion of the Siberian territorial production complexes (including what the proposed sites will produce and at what scale). A cost benefit analysis of the energy production and transmission schemes is compared to the movement of labor and infrastructure from the W. USSR to Siberia.

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Siberian Development and Its Implications to the USSR

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Chapter I

Introduction to the Study

The name "Siberia" has evoked an image of past thoughts of desolation, slave labor camps, forbidding landscapes, and harsh winters. Time has a way of altering perceptions, and our thoughts of Siberia today are changing quickly. The land to the east of the Ural Mountains is a region richly endowed with natural resources. Siberia contains eighty per cent of the Soviet Union's hydroelectric potential, over ninety per cent of its coal reserves, extensive fields of oil and natural gas, and vast deposits of metallic ores (Neporozhnii, 1965, p. 43). Siberia as a whole is just beginning to be developed. Soviet progress in the thirty year period since the World War II reconstruction era has barely scratched the surface of Siberia's broad landscape which covers three-quarters of the USSR and one-eighth of the entire earth's land surface.

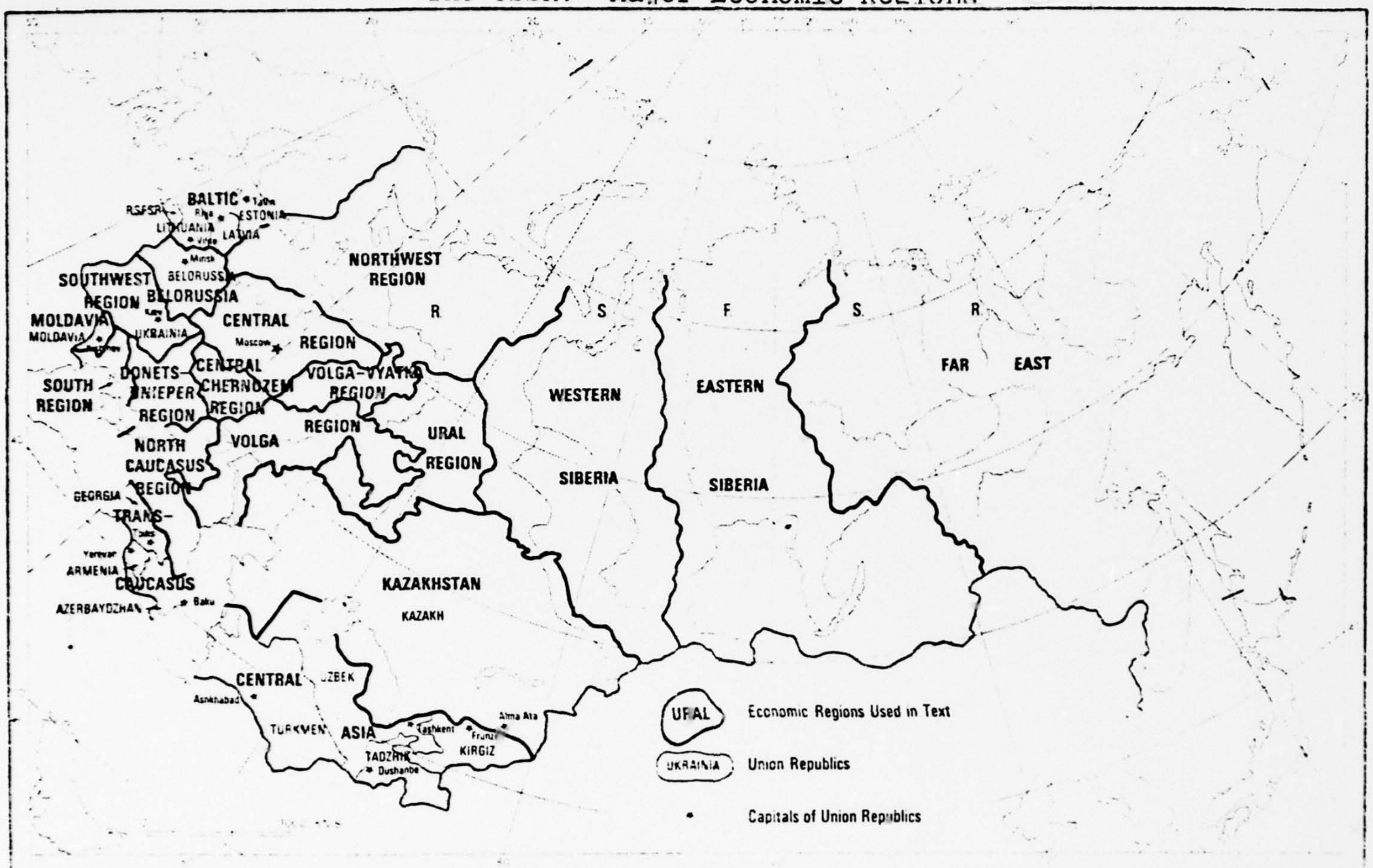
The question of how Siberia should be developed has occupied the thoughts of Soviet planners since Lenin first directed the Soviet Academy of Sciences to outline the development of the state Lenin desired a development scheme whereby all parts of the state could develop equally and equitably.

The purpose of this study is to analyze the development alternatives for Siberia, with a major emphasis on hydroelectric generation of power as a basis for economic

cont

Figure 1-1

The USSR: Major Economic Regions



after Lydolph, 1977, p. vi.

development. The proper balance of capital and human investment in the eastern USSR must be considered against the extremes of the harsh natural environment. The most pressing question in world terms pertains to the methods the USSR will use for the development of Siberia's energy resources. The scheme of Siberian development that the Soviet Union chooses will affect the latter's ability to influence international resource and energy markets. The USSR could industrialize Siberia and use the preponderance of its resources on site. The costs of such a venture are very high in both labor and capital inputs. At the other extreme is a scenario that would entail the export of almost all Siberia's resources in raw form to the European regions of the USSR and to other industrial powers without emphasis on additional or spinoff development in the east. The most probable course of exploitation lies in the spectrum between these possibilities.

Given the restrictions of climate, limited infrastructure and labor supply, this study will suggest that the best prospects for the USSR would be the use of the majority of the Siberian reserves as a source of raw materials and energy to be transhipped to the European regions of the Soviet Union for consumption there and for export to other industrial powers to earn foreign exchange. The development of new technologies make such a hypothesis especially true with respect to energy resources. New

technology has provided specialized transmission systems for liquid fuels and electrical power. In strictly electrical energy terms, the optimal use of the large hydropotential and low grade coal reserves would be a mixture of large hydroelectric stations and minehead coal-fired thermal plants integrated into a national electrical grid in which large portions of the Siberian-generated electricity would be transmitted to western USSR and to Eastern Europe, as opposed to the alternative massive shipments of coal by rail to the central industrial core.

PURPOSE AND METHOD OF THE STUDY

The purpose of this study is to analyze the above hypotheses in order to determine the most efficient economic utilization of Siberian hydro and thermal energy resources. To this extent the study will outline planned and present electrical power generation and transmission. Inherent in this discussion are the spatial manifestations of Siberia's resources and the present plans for their development. A generalized discussion of the development alternatives for Siberia as well as an updated discussion of individual development nodes will be provided. A specific discussion of Siberia's hydropower potential and a discussion of this resource with respect to the technological advent of long distance extra-high-voltage electrical transmission is made in the context of a cost/benefit

analysis of different methods of Siberian energy transfers. The conclusion of the study is designed to show what the development of Siberia means to the USSR as well as its implications for the rest of the world.

LIMITS TO THE DATA AND STUDY

This analysis has the normal limitations of a study pertaining to the USSR: lack of up-to-date and precise data, and contradictions of the Russian materials. Data are lacking, for example, on internal migration of labor; recent estimates of labor reserves in the eastern regions necessitate extrapolations and thus force generalizations. This weakness is especially apparent in any cost/benefit analyses where base figures are not available. To overcome this problem, the costs of similar American, British, or Canadian existing facilities were used and the ruble equivalents substituted at official Soviet exchange rates.

THE REGION TO BE STUDIED

Siberia in the context of this study includes those regions of the USSR to the east of the Ural Mountains (excluding the Ural economic region) and to the north and east of the Kazakhstan and Central Asian regions. It does include the economic regions of Western Siberia, Eastern Siberia, as well as the Soviet Far East.

Figure 1-2 The USSR: Physical Map

Source: The Soviet Union in Maps, 1972, p 2.

Chapter II

European Industrial Core

The Tenth Five-year Plan (1976-1980) appears to be a change from the Eighth and Ninth Five-year Plans. Joseph Berliner has stated, "The Tenth Five-year Plan is a milestone in the change of Soviet economic policy from the classic growth strategy based on increases in factor inputs, to a modern growth strategy based on high rates of technological progress"(1976, p. 446). Robert Jensen suggests that the current Tenth Five-year Plan guidelines provide: "(1) a growing commitment to specialized (as opposed to balanced) development in remote and environmentally harsh areas; and (2) a growing acceptance of a classic core-periphery relationship between the European part of the country and Siberia" (1978, p. 198).

The combination of remote development emphasis with an expansion in the existing industrial core sets the stage for Siberia to be used primarily as a resource store-house of both energy and raw materials. New technology inputs are providing a restructuring of energy transfers from Siberia to the Soviet industrial core at lower total costs. The new economies of scale and high technology enable the Soviets to economically move raw material and energy to the industrial core rather than forcing an expansion of industrial development within

Siberia.

THE EAST - WEST DEBATE

The East-West debate in Soviet terms can be reduced to the question of how Siberia should be developed. Approximately 75 per cent of the population and economic activity of the Soviet Union is located in the western USSR while the opposite amount of water, energy, and important raw materials are in Siberia. Additionally, some important resources, such as oil, gas, and coal, in the European part are being depleted or are becoming more costly to extract than the Siberian resources. This is causing a surge in the transportation of Siberian resources to the European part of the USSR. This massive transfer of materials is being made possible by modern technologies such as oil and natural gas transmission pipelines and the new extra-high-voltage transmission lines to transport large amounts of direct-current electricity over long distances with low losses.

The demands of the industrial core of the USSR for energy and raw materials place heavy emphasis on the eastern region as a source of supply. The related investments in Siberia are thus in the primary economic sectors of mining, lumbering, and energy extractive industries. The industrial requirements of the Soviet industrial core exceed the local production of available energy and

petroleum feedstock supplies in the western USSR.

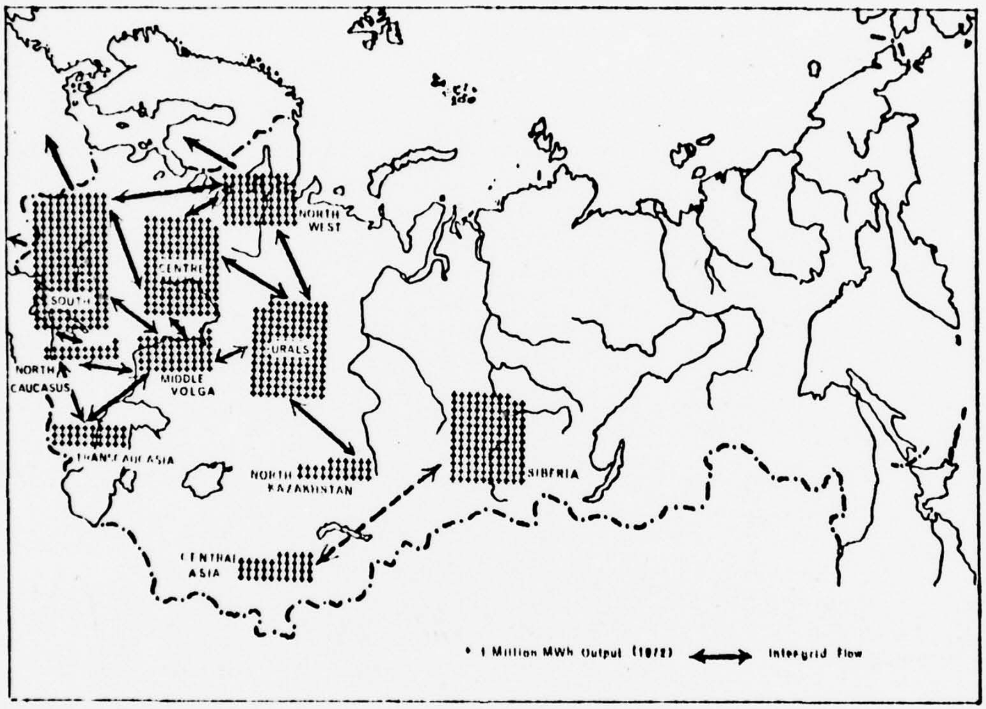
ELECTRICITY

The Soviet consumption patterns can be more readily understood by analyzing a basic industrial energy source, electricity. A disproportionate share of the Soviet Union's electricity is used within the industrial core. Figure 2-1 graphically displays the location of the Soviet industrial core. The electricity consumption has increased during the past five years, accentuating the regional loads and higher demands within the western USSR (Table 2-1). The heavy demand is directly reflected in the electrical grid network distribution (Table 2-2 and Figure 2-2) and rates of production (Table 2-3).

The demands for more energy within the growing industrial core led to quick expansion of thermal and hydroelectrical plants to support the new consumption levels. The most famous of the western USSR's electrical energy sources is probably the Volga Cascade, which has fully harnessed the hydropotential of the Volga River. The Volga hydro stations still only supply limited amounts of power compared to the total demand. During the past twenty years, the Soviet Union has turned heavily toward coal-fired thermal plants to meet increasing demands. The reliance on coal will continue for many years, as it is the major source of electricity in the USSR (Table 2-4).

Figure 2-1

Electricity Output, by Grid (1972)



after Elliot, 1974, p. 227.

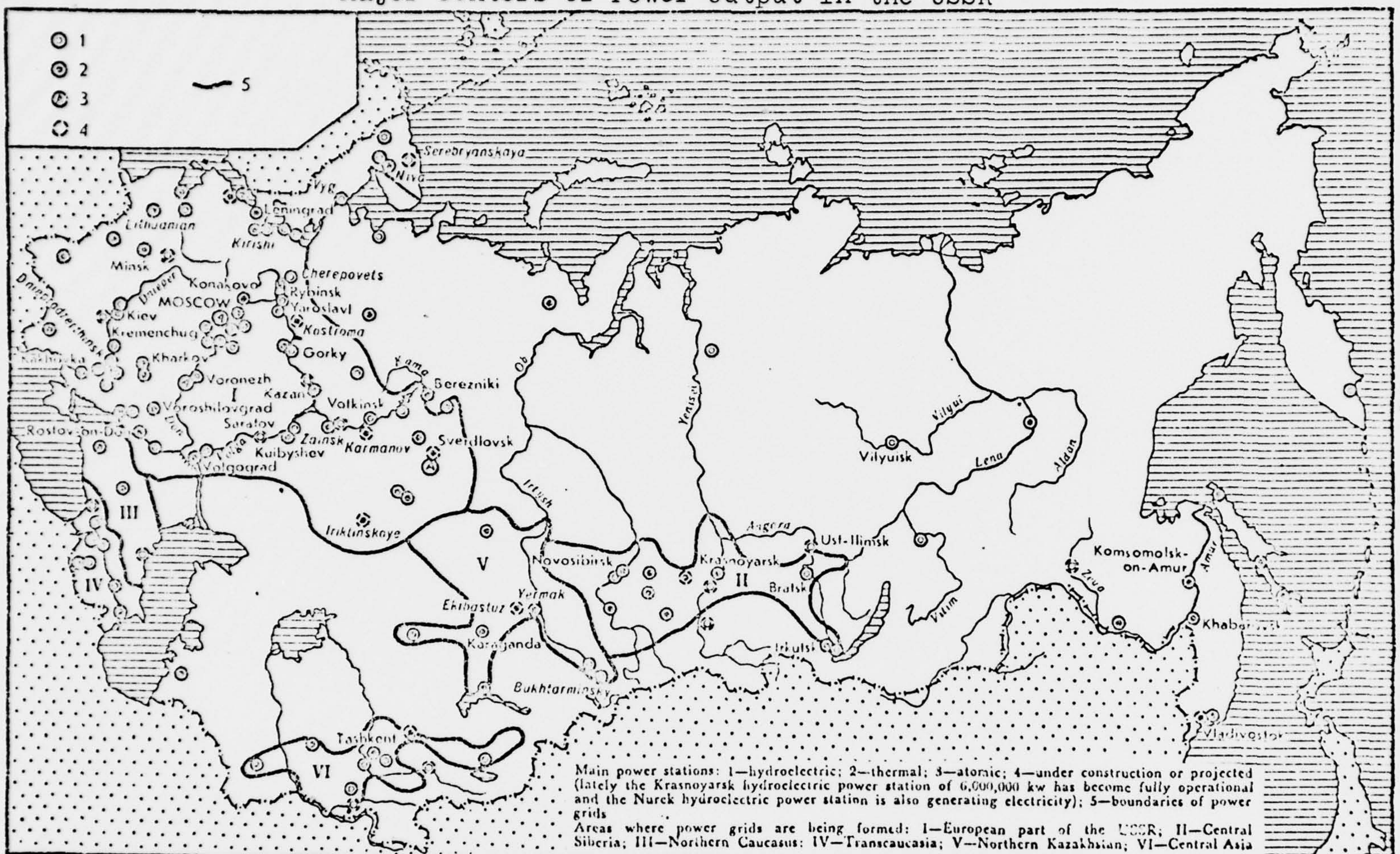
Table 2-1

Geographical Distribution of Soviet Power Generation
(billion kilowatt-hours)

	1965	*1970*	*1975*	*1977*	*1978 Plan*	*1980 Plan*
USSR	507	741	1039	1150	1207	1380
thermal	424	613	892	(970)	(1000)	1103
hydro	81.4	124.0	126.0	(150)	(170)	197
nuclear	1.4	3.5	20.2	(30)	(37)	80
RSFSR	333	470	640	709	744	852
European Russia	170	251	339			
Northwest	25.2	34.4	52.3			
Central	48.9	81.5	114.6			
Volga-Vyatka	12.0	14.9	14.9			
Central Chernozem	8.7	8.6	15.0			
Volga	56.0	80.6	101.9			
North Caucasus	17.7	29.8	39.1			
Urals	75.7	87.1	112.1			
Siberia	87.3	132	189			337
West Siberia	34.9	44.2	70.1			
East Siberia	43.1	74.0	97.2			
Far East	9.3	14.1	21.9			
Ukraine	94.6	138	195	215	224.3	252
Belorussia	8.4	15.1	26.7	30.1	32	34.8
Moldavia	3.1	7.6	13.7	13.59	13.85	15.7
Baltic:	12.5	21.7	28.6	32.9	34.7	34.8
Lithuania	3.9	7.4	9.0	10.7	11.8	12
Latvia	1.5	2.7	2.9	3.3	4.1	4.6
Estonia	7.1	11.6	16.7	18.9	18.8	18.2
Transcaucasia:	19.3	27.1	35.5	38.6	(41)	48.2
Armenia	2.9	6.1	9.2	10.86	12.0	14.5
Azerbaydzhan	10.4	12.0	14.7	15.7	(16)	15.4
Georgia	6.0	9.0	11.6	12.0	13	18.3
Kazakhstan	19.2	34.7	52.5	58.2	61	71.8
Central Asia:	16.8	26.8	47.2	52.7	56.9	74
Kirghizia	2.3	3.5	4.4	4.9	6.5	9
Uzbekistan	11.5	18.3	33.6	34.9	35.6	40.5
Tadshikistan	1.6	3.2	4.7	7.34	8.84	15
Turkmenia	1.4	1.8	4.5	5.59	5.99	9.5

after Shabad, "News Notes," Soviet Geography, April 1978, p. 287.

Figure 2-2
Major Centers of Power Output in the USSR



after Pokshishevsky, 1974, map 18.

Table 2-2

Major Soviet Electric Power Grids

Center--This grid covers 21 oblasts, including Volgograd and Astrakhan, and incorporates the Konakovo thermal power station of 2,400 MW capacity and the 2,530 MW capacity Volga hydroelectric station. It is inter-tied internally with 500 kv lines and externally tied to other grids with 500 and 750 kv lines.

Northwest--This grid covers Belorussia, the Baltic Republics, Leningrad, Novgorod, and Pskov Oblasts, as well as the Karelian ASSR. In 1975 the Kola power system was linked to this grid.

Middle Volga--This network links the Kuibyshev, Saratov, and Penza Oblasts and the Tatar, Chuvash, Mordovian, and Mari ASSRs; it includes among its power stations a 2,300 MW Volga hydroelectric station and the Saratov hydroelectric station of 1,315 MW capacity.

Urals--This covers the Urals area, Tyumen, Kirov, and Orenburg Oblasts, the Udmurt and Bashkir ASSRs, and neighboring regions of Kazakhstan. Its power is mainly derived from large thermal stations.

South--This grid has the greatest capacity of all the grids in the European part of the USSR. It covers the Ukraine, Moldavia, and Rostov Oblast. It employs mainly thermal stations, four of which have a capacity of 2,400 MW and two have a 2,300 MW capacity. A transmission line of 750 kv tension has been constructed over 100 kilometers across the Ukraine from east to west.

North Caucasus-- This small grid covers mainly the Krasnodar and Stavropol Krays and extends to the Caucasus mountain range in the south.

Transcaucasia--This links the power stations, a high proportion of which are hydroelectric, of Georgia, Armenia, and Azerbaidzhan.

North Kazakhstan--This is a comparatively new grid, but it is planned to incorporate thermal stations of up to 5,000 MW capacity based on cheap coal from the Ekibastuz coal basin. A transmission line of 1,500 kv dc is presently under construction (1 Jan 1978) to supply power to the central industrial area grids.

Central Asia--This covers the Uzbek, Turkmen, Kirgiz, and Tadzhik Republics and South Kazakhstan. By 1975, the output from the Nurek, Tokogul, and Karakum high capacity hydroelectric stations were included. A 500 kv transmission line across Kazakhstan was constructed to link the Siberian and Central Asian grids, completing the intertie of all grids in the western region of the USSR.

Central Siberia--This grid incorporates the power stations extending from Lake Baikal on the east to Omsk on the west. This grid had an installed capacity of 26.5 MW in January 1976, amounting to twelve per cent of the Soviet total. Thermal power stations provided 13.6 MW of this capacity, mostly fueled by the cheap opencast coal mines of Western Siberia, while the large Siberian hydroelectric stations of the Angara-Yenisey Cascade (e.g. Bratsk, Krasnoyarsk, Ust-Ilimsk) provided 12.9 MW capacity. The 1980 plan calls for a total capacity of 36 MW, including 17.7 MW in thermal power and 18 MW in hydropower. The local interties are 500 kv lines, with 1,150 kv lines under construction and 1,500 kv dc lines in planning stages.

Far East--In 1972, work was in process to link the power stations of the Amursk and Khabarovsk regions as well as the thermal stations of Sakhalin and Primorsk. More recently the Zeya hydroelectric station is being incorporated as its new generators go on stream.

Table 2-3

Production of Electric Power by Grid (1972)

Grid	Output (in billions of kilowatt-hours)
Center	128.7
Northwest	68.5
Middle Volga	52.3
Urals	128.0
South	178.0
North Caucasus	20.5
Transcaucasia	29.8
North Kazakhstan	25.9
Central Asia	35.4
Central Siberia	117.6

after Elliot, 1974, p. 220-229.
and Shabad, "News Notes," Soviet Geography, 1975-1978.

Table 2-4

Generating Capacity of the Soviet Power Industry
(in million kilowatts)

	1965	1970	1975	1980 Plan
Total Capacity	115	166	218	283
Thermal	81	123	162	202
condenser	48	76	102	127
heat and power	33	47	60	75
Hydro	22.2	31.4	40.8	53.6
Nuclear	0.9	2.4	6.2	19.4
Diesel and others	11	9	9	8

from Shabad, "News Notes," Soviet Geography, Vol. XVII, p. 718.

The Tenth Five-year Plan (1976-1980)

The new five-year plan places fresh emphasis on both hydroelectric and nuclear power production as well as on some expansion of coal-fired thermal plants to reserve oil and natural gas output for the petrochemical industries and export. The advent of new energy technologies will provide a substantial change in the future Soviet power generating capacity (Table 2-5).

The major changes in Soviet electrical production are a greater reliance on nuclear and hydropower. The new emphasis is shown in percentages of total increase; a 159 per cent increase in hydropower generation and a 360 per cent increase in nuclear generation (Table 2-6 and Figure 2-3) compared to a much lower 94 per cent in thermal generation. Approximately 70-million kilowatts

of total new capacity is to be installed by 1980. Much of the increased capacity, or 54 million kilowatts, will be made through expanding present power stations, and the remaining 16-million kilowatts will be in new stations (Shabad, "News Notes," Soviet Geography, Vol. XVII (Nov. 1976), p. 717).

Table 2-5

Structural Changes in New Soviet Power-Generating Capacity

	1971-1975		*1976-80 Plan*		*Percentage change*
Type of Power	*million kilowatt*	*%*	*million kilowatt*	*%*	
Thermal*	45.7	78.0	43.0	61.2	94
Condenser	31.5	53.5	27.0	38.2	82
Heat and power	14.2	24.5	16.0	23.0	112
Nuclear	3.8	6.5	13.7	19.8	360
Hydroelectric	9.0	15.5	13.3	19.0	158
Total	57.5	100	70	100	121

*Condenser plants are large steam-electric stations that use their steam almost entirely for power generation.

Heat and power plants are central heating plants that produce electric power and generate steam for space heating of urban areas and industry.

after Shabad, "News Notes" Soviet Geography, Vol. XVII (Nov. 1976), p. 717.

The proposed new capacity will change the present structure (Table 2-5) to reflect a greater reliance on Siberian hydropower and new nuclear plants in the energy poor Western regions. The increased growth in Siberia will provide a 40 per cent increase in power generation,

Table 2-6

Nuclear Power Reactors in the USSR

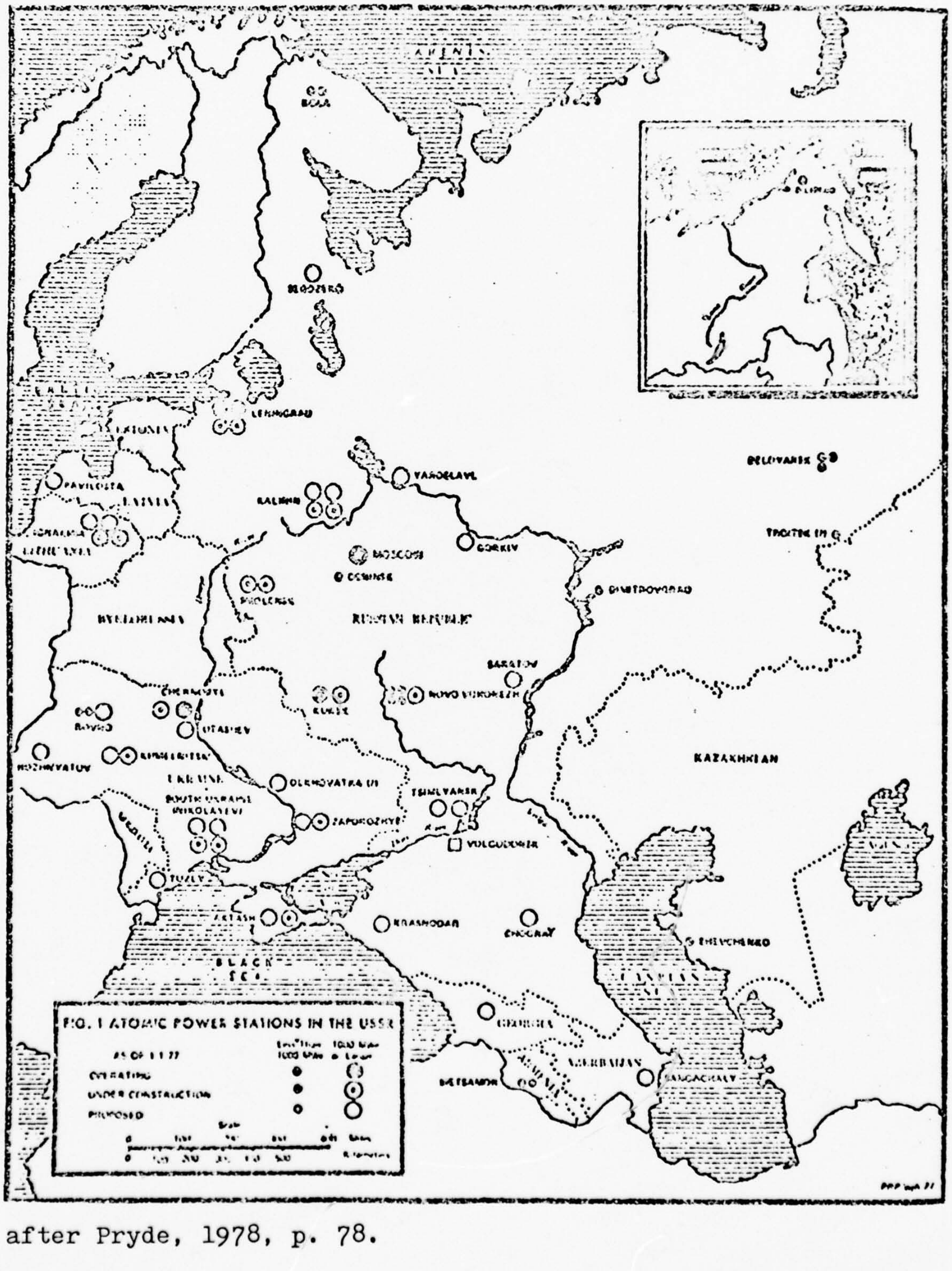
Station Name and Reactor Number	*Station Site*	*Reactor Designation*[a]	*Began Operation*	*Commercial MW(e)*[b, c]
Obninsk	Obninsk	AM-1	1954	5[c]
"Siberian"	Troitsk(?)	(Graphite)	1958	600
Obninsk	Obninsk	BR-5	1959	12[c]
Dimitrovgrad-1	Dimitrovgrad[d]	VK-50	1962	50–70[c]
Beloyarskiy-1	Zarechnyy	AMB-1	1964	100
Novovoronezhskiy-1	Novovoronezhskiy	VVER-1	1964	210–280
Beloyarskiy-2	Zarechnyy	AMB-2	1967	200
Novovoronezhskiy-2	Novovoronezhskiy	VVER-2	1969	365
Dimitrovgrad-2	Dimitrovgrad[d]	BOR-60	1969	12[c]
Novovoronezhskiy-3	Novovoronezhskiy	VVER	1971	440
Shevchenko	Shevchenko	BN-350	1972	150
Novovoronezhskiy-4	Novovoronezhskiy	VVER	1972	440
Bilibino-1, 2, 3	Bilibino	VK-12	1973–75	36
Kola-1	Polyarnyye Zori	VVER	1973	440
Leningrad-1	Sosnovyy Bor	RBMK	1973	1000
Kola-2	Polyarnyye Zori	VVER	1974	440
Leningrad-2	Sosnovyy Bor	RBMK	1975	1000
Bilibino-4	Bilibino	VK-12	1976	12
Kursk-1	Kurchatov	RBMK	1976	1000
Armenian-1	Metsamor	VVER	1976	405
Kursk-2	Kurchatov	RBMK	(1978)	1000
Armenian-2	Metsamor	VVER	(1979–80)	405
Novovoronezhskiy-5	Novovoronezhskiy	VVER	(1978)	1000
Beloyarskiy-3	Zarechnyy	BN-600	(1979–80)	600
Chernobyl'-1	Pripyat'	RBMK	1977	1000
Chernobyl'-2	Pripyat'	RBMK	(1978)	1000
Smolensk-1	Desnogorsk	RBMK	(1979)	1000
Smolensk-2	Desnogorsk	RBMK	(after 1980)	1000
Rovno-1	Kuznetsovsk	VVER	(1979)	440
Rovno-2	Kuznetsovsk	VVER	(1980)	440
Kalinin-1	Udomlya	VVER/RBMK*	(1980)	1000
Kalinin-2	Udomlya	VVER/RBMK*	(after 1980)	1000
Ignalina-1	Snečkus	RBMK	(after 1980)	1500
Ignalina-2	Snečkus	RBMK	(after 1980)	1500
South Ukraine-1	Konstantinovka	VVER	(1979–80)	1000
South Ukraine-2	Konstantinovka	VVER	(after 1980)	1000
Leningrad-3	Sosnovyy Bor	RBMK	(1979)	1000
Leningrad-4	Sosnovyy Bor	RBMK	(1980)	1000

Other sites selected for construction or reported under consideration are Aktash (Crimea), Saratov, Khmelnitskiy, Tsimlyansk, Yaroslavl, Gorkiy, Segozero (Karelia), Pavilosta (Latvia), Krasnodar, Chogray (Stavropol), Sangachaly (Azerbaydzhan), Tuzly (Odessa), Zaporozhye, Otashev (Kiev), Rozhnya[illegible] (Carpathians), and Olkhovatka (Kremenchug?). Of these, only Aktash and Tsi[illegible]yansk had undergone initial site clearing as of Jan. 1, 1978.

after Pryde, 1978, p.80.

Figure 2-3

Atomic Power Sites in the USSR



after Pryde, 1978, p. 78.

from approximately 193-billion kilowatt-hours to an estimated 270-billion kilowatt-hours (Shabad, "News Notes," Soviet Geography, Vol. XVII (Nov. 1976), p. 719). A substantial portion of this increase will be hydropower. The proportion of the Soviet energy balance which will be provided by hydropower in the more distant future is clouded. According to Dienes (1975, p. 10), the proportion of hydroelectricity in the Soviet energy budget will be halved by the end of the century as other power sources expand. This is contradicted by Russian sources (Karaulov, 1967, as quoted in Jackson, 1971, p. 42) who point out that the percentage of hydroelectricity will remain stable into the next century as more and larger hydropower stations are constructed throughout Siberia. The Fifthteen-year Plan newly published by Gosplan USSR in 1977 calls for enhanced development of fuels, energy, raw-material and water resources in the eastern regions of the Soviet Union, with particular attention to the "hydroelectric potential of the Ob, Yenisey, Lena, Amur, Amudarya, and Naryn rivers" (Shabad, "News Notes," Soviet Geography, Vol. XVIII (Nov. 1977), p. 699).

Growth within the Soviet industrial core during the remainder of the twentieth century will certainly expand the Soviet energy requirements. Any projection (Table 2-7) must include all inputs into the energy balance. The output, or consumptive balance is considerably different.

The 1980 Plan calls for 1,380-billion kwhrs of electricity (Table 2-1). The projections for 1980 and 1990 (Table 2-7) do not show that the generation of 1,380-billion kwhrs is equivalent to 475-million standard fuel tons. This total is more than 25 per cent of total energy consumption in the USSR. As technology and energy transfers increasingly rely on electrical transmission, a growing percentage of Soviet energy end-consumption will be in the form of electricity.

TRANSPORTATION OF FUELS

The distance of the central industrial core from the Siberian energy resources dictates that either massive transfers of raw energy and materials be carried to the industrial core, or that new production facilities be built in Siberia. The Tenth Five-year Plan guidelines do give much emphasis to Siberia. However, the major projects, including the Baikal-Amur mainline railroad, hydroelectric dams, and energy and industrial resources all point toward resource extractions in Siberia for consumption in the western USSR. To again quote from Robert Jensen (Soviet Geography, Mar. 1978, P. 199):

> "What may have changed is the traditional 'grand view' of comprehensive Siberian development. The present guidelines, more than previous ones in my view, suggest a growing acceptance of a classic core-periphery relationship between West and East, with Siberia supplying raw materials and energy to the more developed European regions. Such acceptance would accord with

Table 2-7

Projections of the Soviet Energy Balance: 1980 and 1990

	Production in physical units	Net exports in physical units	Consumption in physical units	Consumption in SF[a] equivalent (mil. tons)
PROJECTIONS FOR 1980				
A. By energy sector				
Natural gas (bil. cu. meters)	400-435	35	390	466
Petroleum (million tons)	620-640	120[b]	510	729
Peat (million tons)	67	—	67	25
Shale (million tons)	44	—	44	15
Wood	n.d.	—	n.d.	20
Hydroelectricity (bil. kwh.)	200	—	200	25 (65)
Nuclear power (bil. kwh.)	80	—	80	10 (26)
Coal and lignite (mil. tons)	790-810	20	780	540
B. Overall consumption				1,830 (1,886)
PROJECTIONS FOR 1990				
A. Overall consumption				
Assuming annual growth (1980-90) of 4.5 percent				2,842 (2,929)
Assuming annual growth (1980-90) of 4.7 percent				2,897 (2,985)
Assuming annual growth (1980-90) of 5.0 percent				2,981 (3,072)
B. By energy sector				
Natural gas (bil. cu. meters)	900	90	810	968
Petroleum (million tons)	800	100[b]	700	1,001
Peat (million tons)	85	—	85	31
Shale (million tons)	65	—	65	22
Wood	n.d.	—	n.d.	10
Hydroelectricity (bil. kwh.)	285	—	285	35 (86)
Nuclear power (bil. kwh.)	450	—	450	55 (135)
Coal and lignite (mil. tons)[c]	1,165 (1,060)	30	1,135 (1,030)	720 (676)
	1,270 (1,185)		1,240 (1,155)	775 (732)
	1,495 (1,375)		1,465 (1,345)	859 (819)

NOTE: Figures in parentheses throughout the table reflect an alternative calculation for the energy contribution of *primary electricity*, i.e., hydroelectric and nuclear power. Original calculations were made at the actual heat value of electricity—123 grams of standard fuel (or 861 kilocalories) per kilowatt-hour. The alternative calculation reflects the fuel required to generate the same number of kilowatt-hours in conventional thermal plants. Assuming a steady technological advance, the author set this figure at 325 grams of SF (or 2,282 kcal.) per kwh. In 1980 and at 300 grams of SF (or 2,100 kcal.) per kwh. in 1990. The original calculation reflects the virtual 100-percent efficiency of converting electricity to heat. The alternative calculation reflects the thermodynamic limitations on conversion of heat to electricity, which yields only 40-percent efficiency in modern thermal plants and considerably less in entire thermal systems. The first understates the contribution of primary electricity, since electricity is a more flexible and valuable form of energy than heat. The alternative probably overstates the contribution of primary electricity, since many conventional thermal stations provide both useful heat *and* electricity, which hydro plants and even nuclear plants are still unable to do.

After Dienes, 1977, p. 43.

> the general impact of improved technology, the current Soviet emphasis on labor productivity and growth based on technological progress, and a notable lack of success in attracting a permanent labor force to Siberia."

The Costs Of Energy Transfers

The implicit costs of maintaining and supporting an industrial core in the western USSR are the transport costs of moving raw materials from their sources to the central industrial locations. Tables 2-8 to 2-17 contain the raw data of extraction, transportation and delivery costs for the fuels needed to supply the central industrial base. These data show the lower extraction costs of oil, natural gas, and coal in Siberia as compared to the same products in the European part of the USSR. The new emphasis on the core-periphery model in the USSR is possible only when viewed through the advent of lower transportation costs which enable raw materials from the periphery to compete economically with like materials from other sources. The relatively lower cost of abundant Siberian resources is partially derived from the increased costs of extractions in the European region where these resources are partially depleted and the lower costs of transportation provided by new technology for the distant Siberian resources. This means that coal can be mined in Western Siberia (Kuzbas) and delivered to Moscow cheaper than it can be delivered to Moscow

from the Moscow coal basin. Examples of the comparative advantages of Siberian hydropower (Chapter III), as the least expensive electricity, show how technology has changed the economic viability of Siberian resources in the USSR's central industrial base.

Table 2-8

Soviet coal extraction costs
(Production costs plus geological and amortization costs)
(Rubles per ton of standard fuel)

	Costs in 1970	Latest costs estimates*
Donets		
Old mines	14·8	11·2
New mines	16·9	
Kuznetsk		
Old mines	8·8	10·6
Reconstructed opencasts	6·8	4·8
New opencasts	7·7	
Pechora		
Old mines	8·2	19·5†
New mines	7·7	
Old opencasts	4·0	
Kansk–Achinsk		
Coal	1·3	2·0–4·0
Lignite		1·7–1·8
Ekibastuz		2·1†
Old mines	2·2	
New mines	2·8	
Far East		3·9–17·3**
Old mines	14·5	
New mines	13·2	
New opencasts	5·8	
Minusinsk		4·7
Karaganda		9·8
Podmoscow (lignite)		14·3
Kizelov		15·3
Lengerov		23·4
Kirghiz		12·9

*Figures refer to expected production costs 1975–1990 and include a 12·5% simple interest charge on investment.
†Type of mine not specified.
**Estimates for a whole range of mines in the area.
Sources: Melnikov, pp. 179–80; Probst, *Vopr.ekon.*, 6(1971); Dienes, *Energy policy*, June 1973; *Plan.khoz.*, 2 (1975).

after Russell, 1976, p. 218.

Table 2-9

Delivered costs of Soviet coal to central regions and Urals
(Rubles per ton of standard fuel)

Source of coal,	Extraction area	Leningrad	Moscow	Riga	Minsk	Voronezh	Gorkii	Donets–Dnepr	Sverdlovsk	Magnitogorsk
Donbass	15·3	20·3	18·4		18·6	17·5	18·8	15·6		
Pechora	13·4	17·6	19·7*							
Moscow (Lignite)	20·9		23·1							
Kuzbas (general)										11·6*
Mine	11·0	18·1	21·5*	19·0	18·0	17·7	16·6		14·6	14·6
Opencast	7·7	16·3	17·6*	17·4	16·3	15·9	14·4		12·2	12·5
Ekibastuz	2·8		14·6*			11·7				8·1*
Kansk–Achinsk										
Dried fines	4·2	14·1	12·5	14·8	13·8	13·0	12·5	14·5	10·0	10·3
Semi coke fines	4·3	11·7	10·5	12·2	11·5	10·7	10·5	12·0	8·7	8·9
Semi coke nuts	4·5	11·9	11·0	12·7	11·3	11·6	10·5	12·5	8·8	9·0
Lignite	1·6		24·8*							
Kazakhstan										
Open pit		17·3	20·8*			15·2	15·0			

*Estimated from recent data.

Table 2-10

Cost of coal transportation
(Rubles per ton of standard fuel)

Source	Method	Distance 1,000 km	2,000 km	3,000 km	4,000 km
Kuznetsk	Rail	3·2	6·2	9·2	
Ekibastuz	Rail	4·2	8·2	12·1	
Kansk–Achinsk	Rail	5·4	10·4	15·4	
Not Stated	*Rail*				
6000 kcal/kg		1·9	4·0	5·6	7·0
3500 kcal/kg		3·2	6·8	9·6	12·0

Sources: Probst, *Vopr.ekon.*, 6 (1971) and Melnikov, p. 183.

after Russell, 1976, p. 219.

Table 2-11

Soviet crude oil extraction costs
(Production costs plus geological and amortization costs)
(Rubles per ton of standard fuel)

	Cost in 1970	Latest cost estimates
Komi ASSR	10·8	6·8†
Orenburg and Perm	10·3–10·5	
Bashkir ASSR	8·9	10·0
Tatar ASSR	6·1	7·1
Volga–Urals		7·3*
Kuibyshev Oblast	8·0	
Stavropol and Krasnodar Krai	11·4–15·2	
Chechen–Ingush ASSR	14·0	
Tyumen Oblast	6·2	9·0–12·0
Irkutsk Oblast	9·1	
Ukraine	9·3	7·9*
Azerbaidzhan	18·7	20·8†
Turkmenia	15·9	
Kazakhstan	6·6	
(Mangyshlak)	(6·2)	(4·5)
Belorussia		8·5*

*Estimated 1975 costs.
†Cost of production from newly completed wells (1973).
Sources: Melnikov, p. 179; *Vyshka,* 12 Dec. 1973; *Problemi severa,* 1971, pp. 56–62; *Ek.neft.prom.*, Dec. 1972; *Plan.khoz.*, 2 (1975).

after Russell, 1976, p. 216.

Table 2-12

Delivered cost of Soviet crude oil
to central areas and Urals
(Rubles/ton of standard fuel)

Crude oil sources	Extraction area*	Leningrad	Moscow	Riga	Voronezh	Gorkii	Sverdlovsk	Magnitogorsk	Donets–Dnepr	Minsk	Ukraine
Tyumen	5·2		8·4				14·7		15·7		17·8
Urals	7·2†		8·0								
North Caucasus	8·8										
Komi	9·7										
Mangyshlak			9·5								
Belorussia	10·4										
Ukraine	10·6										
Fuel oil		9·4	8·1	9·2	11·6	7·7	7·3†	11·9	10·8	9·3	

*i.e. delivered cost of crude to local refinery.
†Volga–Urals.
Sources: A Probst, *Vopr. ekon*, 1971, no. 6, p. 56; Melnikov, p. 183; *Ek.neft. prom.*, Oct 1973.

Table 2-13

Cost of crude oil transportation
(Rubles/ton of standard fuel)

Method	Distance (km)		
From Tyumen and Tatar, ASSR			
Pipeline	1,000	2,000	3,000
520 mm	1·9	3·7	5·6
720 mm	1·1	2·1	3·1
1,020 mm	0·7	1·5	2·2
1,220 mm	0·7	1·3	1·9
Rail	3·0	5·5	7·9
From Tyumen			
Pipeline			
1,420 mm	0·4	0·9	1·3
From Mangyshlak			
Pipeline			
1,420 mm	0·6	1·1	1·6

after Russell, 1976, p. 217.

Table 2-14

Soviet gas extraction costs
(Production costs plus geological and amortization costs)
(Rubles per ton of standard fuel)

	Costs in 1970	Latest estimates
Ukraine	5·5	7·4*
Stavropol	4·5	
Krasnodar	4·8	8·2*
Azerbaidzhan	13·2	
Volgograd	9·7	9·7*
Tyumen	2·2	3·0–5·0
Turkmenia	4·1	
Uzbekistan	5·5	
Tomsk	6·5	
Yakutsk	5·2	
Central Asia	5·4	5·5–6·0
Orenburg		2·9
Komi		6·1
(Vuktyl)		(3·0)*

*1975 cost estimates.
Sources: Melnikov, pp. 178–9; *Problemi severa;* publ. no. 15, 1971; *Plan.khoz.*, 2 (1975); *Vopr.ekon.* 8 (1973).

Table 2-15

Delivered costs of Soviet natural gas
to central regions and Urals
(Rubles per ton of standard fuel)

Source	Extraction area	Leningrad	Moscow	Riga	Minsk	Voronezh	Gorkii	Donets–Dnepr	Sverdlovsk	Magnitogorsk
Tyumen	2·2	10·8	13·4–14·3	10·0	11·4	13·3*	10·0			
Central Asia			10·1–10·9			10·4		12·9		
Komi (Vuktyl)			7·1							
Uzbekistan	5·7		9·9			8·2				8·2
Stavropol	4·6							6·2		
Turkmenistan	4·2		8·5			9·6		9·1		

*Saratov
Sources: Melnikov, p. 183; Probst, *Vopr.ekon.*, 6 (1971); *Geologiya neft i gaza*, Oct 1972.

after Russell, 1976, p. 220.

Table 2-16

Cost of gas transportation
(Rubles per ton of standard fuel)

Source	Method	Distance (km)		
	Pipeline	1,000	2,000	3,000
Tyumen	1,420 mm	2·2	4·3	6·5
	2,520 mm*	1·4	2·8	4·2
Central Asia	1,420 mm	2·2	4·3	6·5
Not stated	1,020 mm	2·6	5·3	
	1,220 mm	2·3	4·58	
	1,420 mm	2·2–2·3	4·3–4·9	
	2,020 mm*	1·6–1·9	3·2–4·0	
	2,520 mm*	1·4–1·6	2·8–3·3	

*Estimated

after Russell, 1976, p. 221.

Table 2-17

DELIVERED COSTS OF STANDARD FUEL EQUIVALENTS FROM SELECTED SITES AND DESTINATIONS
(Rubles per Ton of SF)

EXTRACTION AREA/COST	MOSCOW	GORKI	LENINGRAD	MINSK	VORONEZH	DONETS	KIEV
Tyumen (Oil, 5.2)	8.4	7.7	9.0	16.5	8.2	15.7	16.4
Tyumen (gas, 4.0)	13.4	10.0	10.8	11.4	13.3	10.9	12.0
Donbas (coal, 15.3)	18.4	18.8	20.3	18.6	17.5	15.3	17.2
Kuzbas (coal, 11.0)	18.1	16.6	21.5	16.3-18.0	17.7	20.0	21.4
Ekibastuz (coal, 2.8)	14.6	13.8	14.9	16.1	11.7	14.5	15.3
Central Asia (gas, 6.0)	10.5	11.2	12.1	11.8	10.4	11.2	11.6
Kazakhstan (coal, 9.8)	20.8	15.0	17.3	16.8	15.2	15.6	16.2
Uzbekistan (gas, 5.7)	9.9	10.6	11.5	11.8	8.2	10.5	11.2
Pechora (coal, 13.4)	19.7	18.4	17.6	22.4	20.4	24.1	24.1
Angara/Yenisey hydro 15,000 MW at 1000 kv-dc w/10% line loss	2.000	1.919	1.250	2.169	2.100	2.110	2.168
Angara/Yenisey hydro 7,500 MW at 1000 kv-dc w/10% line loss	2.138	2.126	2.485	2.493	2.31	2.251	2.490
Angara/Yenisey hydro 4,000 MW at 750 kv-dc w/15% line loss	2.879	2.680	3.144	3.210	2.989	3.082	3.209
Angara/Yenisey hydro 1,500 MW at 500 kv-dc w/20% line loss	5.02	4.555	5.644	5.799	5.281	5.498	5.778

Sources: Tables 2-9, 2-12, 2-15; calculations from combinations of Tables 2-8, 2-10, 2-11, 2-13, 2-14, 2-16; calculations in accordance with Table 3-11, Figure 3-4 (for costs of delivered Angara/Yenisey hydrofuels).

Chapter III

The Resource Potential Of Siberia And Its Development

RESOURCES TO BE DEVELOPED

A major problem in the USSR today, as in the rest of the industrialized world, is for energy and raw materials to satisfy the requirements of the industrial base. Siberia contains a wealth of both commodities and is expanding its contribution to the economy (Table 3-1). The most spectacular recent developments have been in the exploitation of oil and natural gas in the Ob River basin of Western Siberia. This has followed closely on the hydroelectric dams on the Angara and Yenisey Rivers in East Siberia and the associated coal field developments. Siberia also holds large deposits of copper, nickel, gold, and rare metallic ores. These mineral resources must be developed rapidly to meet industrial demands. The accompanying map (Figure 3-1) shows the locations of possible development sites based near the mineral deposits. Is is most reasonable to assume that the resources to be developed first will be those which are most accessible or will shortly become accessible through new transportation networks, such as the Baikal-Amur Mainline (BAM) railroad (Figure 3-1), which is to penetrate the middle latitudes of eastern Siberia for the first time.

Table 3-1

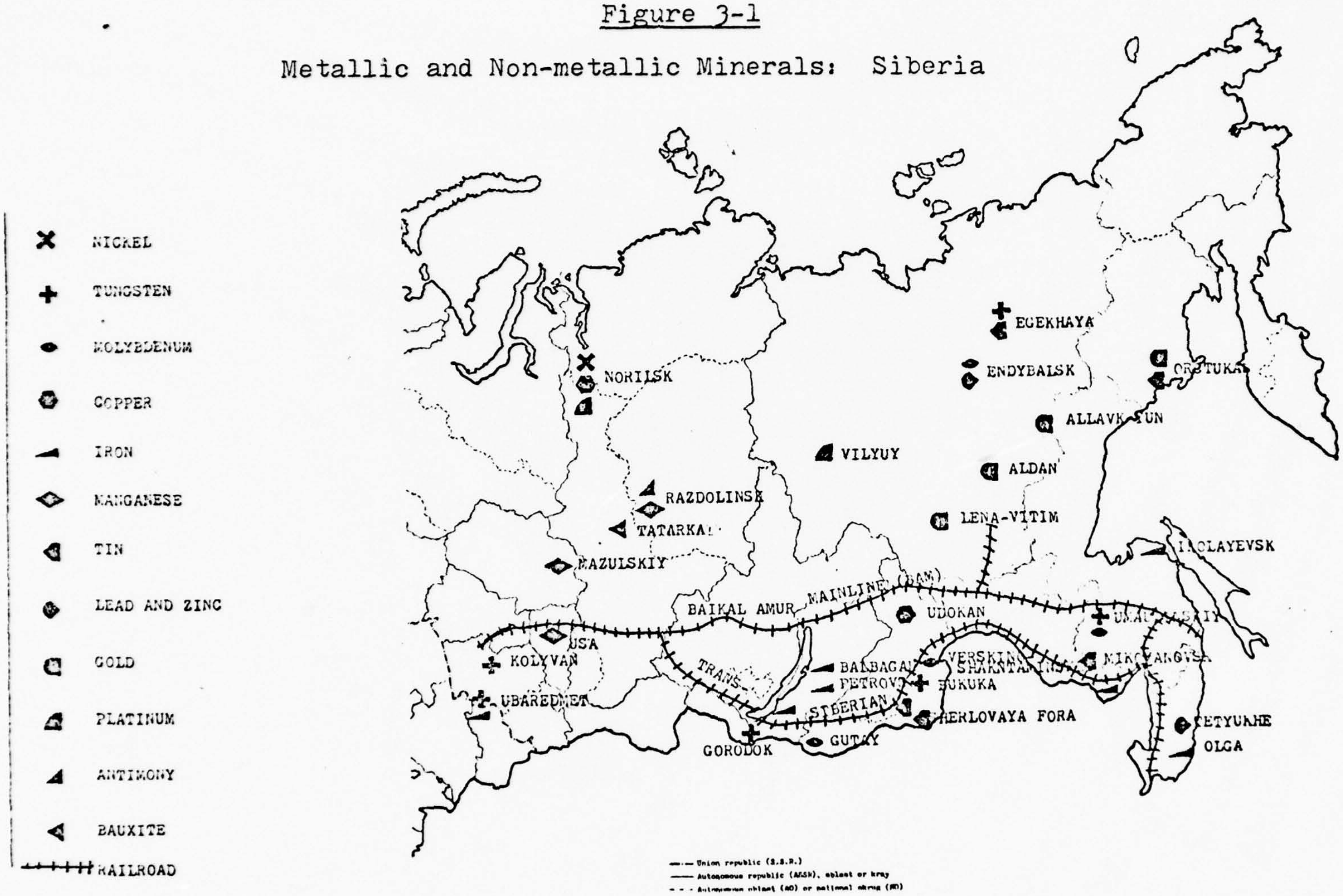
Siberia's Contribution to the Soviet Economy
(in per cent of national output)

Energy resources	1940	1950	1960	1970	1973	1975
Coal	23	27	28	32	33	34
Coking coal	17	29	26	29	30	31
Oil	1.6	1.6	1.1	9.6	21	31
Natural gas	-	1.5	0.7	5.0	8.5	14
Electric power						
Capacity	7.2	12	15	20	19	
Output	6.6	11	15	18	18	
Hydro output	4.4	3.6	10	36		
Wood Products						
Roundwood	23	23	26	33	34	
Sawnwood	23	19	23	26	27	
Pulp	-	4.3	9.3	20	22	
Paper	0.1	5.2	7.3	8.9	7.0	
Paperboard	0.5	4.3	8.0	16	18	
Iron and steel						
Iron ore	1.6	5.5	5.7	6.5	6.9	6.4
Pig iron	10	10	7.1	8.5	9.5	9.0
Crude steel	10	13	8.4	8.1	8.3	9.0
Rolled steel	9.1	15	10	8.9	10	
Consumer durables						
Radios	-	13	19	24	20	
Refrigerators	-	-	-	18	15	
Washing machines	-	-	13	13	15	
Food products						
Meat	13	12	11	9.1	10.1	
Butter	23	17	13	12	12	
Population	8.9	-	10.8	10.5	10.5	

after Shabad and Mote, 1977, p. 54.

Figure 3-1

Metallic and Non-metallic Minerals: Siberia



FOREST RESOURCES

The Siberian taiga is covered with marketable timber and provides the USSR with rich resources for an extensive forst products industry. These forest resources form the basis for several proposed industrial development nodes. In the regions to be opened by the BAM, seven out of the ten planned complexes will have forest product industry as the principal or secondary specialization (Gorovoy, 1978, p. 84). The opening of the BAM railroad will immediately provide an additional 20-million hectares of standing timber reserves, providing a total of 4-billion cubic meters of lumber, of which 2.89-billion cubic meters are found in mature and over mature forest stands. The most important commercial timber areas to be opened will be in the Upper Lena, Kirenga, Selemdzha, Amgum, and Lower Amur basins (Kibalchich, 1976, p. 389). The development of these forest resources will require the construction of several large processing complexes to provide a wide range of forest products: sawnwood, plywood, prefabricated housing sections, wood pulp, paper, paperboard, yeast, chipboard, and fiberboard. It has been estimated by O.P. Kibalchich of the Gosplan, RSFSR Central Economic Research Institute, that the development of the forest products industry in the BAM regions will cost as much as the total regional investment in iron, steel, and nonferrous metal industry (Kibalchich, 1976, p. 391). The present level

of Siberian forest products production could double with the increased accessibility provided by the BAM construction. This production increase is expected to equal ten per cent of present total Soviet production (Gorovoy, 1978, p. 84).

Table 3-2

Timber Resources of the BAM Zone

	Area in mill. hectares		Growing stock, in bill. m^3	
Subzones and administrative subdivisions	*Forest covered*	*Commercial timberlands*	*Mature stands*	*Merchantable*
I. Subzone in immediate proximity of the BAM	34.9	13.6	2.89	1.74
1. Irkutsk Oblast	5.6	2.2	0.43	0.38
2. Buryat ASSR	3.4	1.3	0.31	0.13
3. Chita Oblast	3.1	0.7	0.23	0.08
4. Yakutsk ASSR	0.6	0.3	0.05	0.02
5. Amur Oblast	11.6	3.8	0.80	0.44
6. Khabarovsk Kray	10.6	5.3	1.07	0.69
II. Subzone under influence of the BAM	60.4	23.4	6.28	2.96
1. Irkutsk Oblast	12.5	5.8	1.29	0.77
2. Yakut ASSR	37.3	12.9	3.82	1.52
3. Khabarovsk Kray	10.6	4.7	1.17	0.67
Total BAM zone	95.3	37	9.17	4.70

after Gorovoy and Shlykov, 1978, p. 86.

Table 3-3

Possible Future Structures of Forest Industries in the Logging Districts of the BAM Zone

Projected logging districts and processing complexes	*Possible volumes (mill. m^3) of:* Roundwood removals	*Roundwood processing**	*Projected processing industries*
Upper Lena district	11.7	14.7	Sawmilling Fiberboard and particleboard Chips Plywood Pulp Fodder yeast
Ust'-Kut complex	2.5	2.6	Sawmilling Fiberboard and particleboard Chips Yeast
Kazachinsk complex	3.9	5.6	Sawmilling Fiberboard Chips Pulp
Kirensk complex	5.3	6.5	Sawmilling Fiberboard Plywood Chips Pulp
Baykal-Udokan district	0.2	–	–
Tynda district	2.4	0.3	Sawmilling
Zeya district	3.4	–	–
Urgal district	4.6	0.4	Chips
Komsomol'sk-Amursk district	7.0	7 to 8	Sawmilling Railroad ties Wood processing Plywood Furniture Fiberboard Chips Pulp Paperboard
Lena-Bodaybo district	0.5	–	–
Olekma district	0.3	–	–
Aldan district	0.3	–	–
Uda district	0.1	–	–

*Including use of wood waste and roundwood hauled from other districts.

after Gorovoy and Shlykov, 1978, p. 91.

HYDROPOWER POTENTIAL AND PHYSICAL DATA

The Soviet Union has an extremely large energy resource in its hydropower potential. This natural energy source is estimated to be 11.5 per cent of the world's total hydropower reserves (Table 3-4). Only the People's Republic of China has a greater potential for the production of hydropower. The economic potential of the USSR, which includes only those hydraulic sites where hydropower is available in industrial volumes, is greater (1720-billion kwhr/year) than the total planned Soviet electrical generation for 1980 (1380-billion kwhr/year).

Table 3-4

Hydropower resources of various countries

Continent	Estimated reserves: million, kw	Estimated reserves: billion kwhr/year	% of total	Country	Economic potential, billion kwhr/year (tentative)	Resources as million kwhr/1000 people
Asia	1,340	11,750	35.7	World	10,000	—
Africa	700	6,150	18.7	China	2,000	3.3
North America	700	6,150	18.7	USSR	1,720	8.6
South America	600	5,250	16.0	U.S.A.	491	2.9
Europe	240	2,100	6.4	Canada	325	20.0
Australia	170	1,500	4.5	India	200	0.6
				Brazil	115	2.7
				Japan	103	1.1
Total	3750	32,900	100.0	Norway	100	29.4
				Turkey	90	5.3
				Sweden	80	10.9
Including:				France	65	1.4
USSR	434	3,800	11.5	Italy	55	1.1
China	544	4,750	14.4	Austria	40	5.7
U.S.A.	—	1,500	4.5	Argentina	32	2.5
Canada	—	1,000	3.0	Spain	32	1.3
				Switzerland	30	7.5
				German Federal Republic	16	0.3

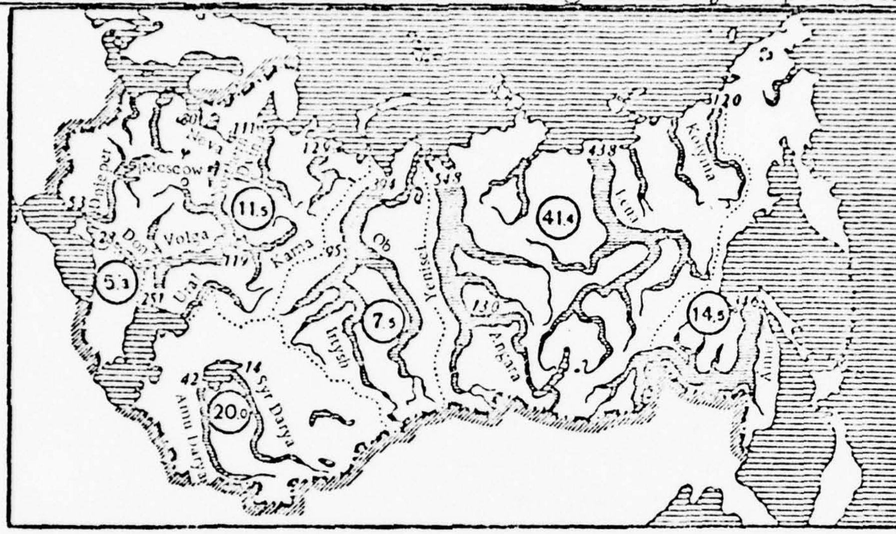
after Nesteruk, F. Ya., 1963, p. 40.

F. Ya. Nesteruk of the Soviet Academy of Sciences, however, has given lower estimates. According to Nesteruk, it is technically feasible to build 2000 hydropower plants with a total capacity of 125,000 MW and an annual production of 650-billion kilowatt-hours in the USSR. But technical feasibility must give way to economic feasibility which reduces the figure to 1600 hydroelectric stations (HES) producing 95,000 MW or almost 500-billion kwhr per year (Nesteruk, 1963, p. 39). Another source, Jackson (1971, p. 42), in his review of total Soviet energy reserves, recognized figures of 1,720.8-billion kwhr per year as the technically feasible production and 1206.1-billion kwhr of hydropotential available in industrial volumes. I. Elliot (1974, p. 218) quoted a figure of 120,000 MW of available hydropower in his assessment of Soviet reserves. The data differ from source to source, but it appears that the USSR has at least 100,000MW of usable hydropotential, which could provide over 500-billion kwhr of electricity annually.

The second factor in this assessment of Soviet hydropower lies in the geographical dispersion when related to the Soviet industrial base. The schematic map (Figure 3-2) shows both the general location of the major hydropower potential regions as well as the important geographically skewed balance in favor of Siberia. In an analysis of the potential effects of hydropower

Figure 3-2

Soviet River Flow Volumes and Regional Hydropotential



a) The circled figures give hydropower reserves of each region (dotted lines) as percentages of the total Soviet reserves.

b) The non-circles numbers are river flow in km3 per year.

after Nesteruk, 1963, p. 38.

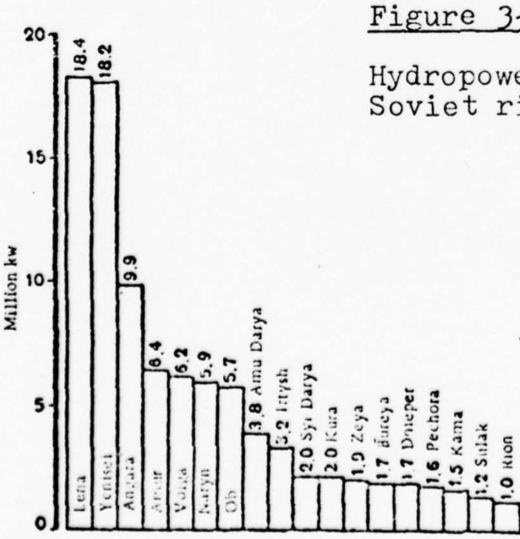


Figure 3-3

Hydropower potential of the largest Soviet rivers in millions of kilowatts

after Nesteruk, 1963, p. 38.

development in the USSR, Siberia stands out in three areas. First the physical potential of the Siberian rivers is high (Tables 3-5 and 3-6) due to the large heads produced as the rivers fall from the high plateaus of Siberia combined with the immense volumes of water drainage from the extended Siberian catchment basins. This Siberian potential is estimated to be 62.5 per cent of the total hydroenergy reserves of the USSR. Secondly, the distance in kilometers from the Siberian hydropower sites to the central industrial base of the USSR is on the order of 2000 to 5000 kilometers. The movement of hydroelectricity over those distances is costly, but technically feasible with existing technology (Table 3-11). This is somewhat balanced by the very low cost of construction at the HES sites per kilowatt-hour produced. Finally, the potential for additional hydropower construction in the European parts of the USSR is limited. It is estimated by Kudoyarov (1975, pp 208-212) that 55 per cent of the available economically usable hydropower in the European USSR has been exploited. A few more sites in the European part are of reasonable productivity and they are being assessed for utilization, but further construction of dams in the European part of the country would probably be of a low cost/benefit ratio because further inundation of low head sites results not only in low power generation, but also in further loss of agricultural lands.

Table 3-5

Hydropower potential of Soviet rivers

River	River basin	Hydropower potential, thousand Mw
Lena	Laptev Sea	> 20
Yenisei	Kara Sea	18.2
Angara	Yenisei	14.0
Amur	Sea of Okhotsk	> 10*
Volga	Caspian Sea	11.8
Indigirka	East-Siberian Sea	6.2
Naryn	Syr Darya	5.9
Pyandzh	Amu Darya	5.8
Ob	Kara Sea	5.7
Aldan	Lena	5.5
Vitim	Lena	5.4
Kolyma	East-Siberian Sea	5.2
Lower Tunguska	Yenisei	4.2
Khatanga	Laptev Sea	4.1
Vakhsh	Amu Darya	4.1
Olekma	Lena	4.0
Amu Darya	Aral Sea	3.8
Katun	Ob	3.7
Irtysh	Ob	3.2
Bartang	Amu Darya	2.4
Vilyui	Lena	2.4
Syr Darya	Aral Sea	2.0
Kura	Caspian Sea	2.0
Zeya	Amur	1.9
Bureya	Amur	1.7
Dnieper	Black Sea	1.7
Pechora	Arctic Ocean	1.6
Kama	Volga	1.5
Sulak	Caspian Sea	1.2
Rion	Black Sea	1.0
Razdan	Lake Sevan	0.6

The available water power resources were calculated by the formula:

$$N_{kw} = 9.81QH$$

H=Gross head over a given stretch in meters

Q=Average discharge in m^3/sec through the stretch

Table 3-6

Hydropower resources of the economic regions of the USSR

Region	Area, thousand km^2	Hydropower potential			Practically exploitable energy resources		Share of hydro-power in total power supply, %
		thousand kw	billion kwhr	% of total	thousand kw	billion kwhr	
North-West	488.1	3,589	31.4	1.1	2,400	21	36.8
North	1,146.2	6,614	57.9	1.9	2,850	25	15.0
Central area	983.1	3,720	32.6	1.1	1,710	15	
Volga area	480.4	6,456	56.6	1.9	4,910	43	41.5
Ural Area	384.3	5,009	43.9	1.5	2,170	19	
Northern Caucasus	760.2	11,291	98.9	3.3	4,576	40	34.3
Western Siberia	2,423.6	24,132	211.4	7.1	14,840	130	5.1
Eastern Siberia	7,410.2	140,815	1,233.5	41.4	91,320	800	19.9
Far East	2,915.1	47,536	416.8	14.0	28,540	250	34.4
West	398.2	1,782	15.7	0.5	1,140	10	33.9
South	610.4	5,412	47.4	1.6	2,170	19	8.0
Transcaucasia	191.7	16,623	145.6	4.9	7,310	64	78.5
Soviet Central Asia	1,231.8	51,908	454.8	15.3	25,680	225	51.4
Kazakhstan	2,753.8	15,063	131.9	4.4	6,850	60	
Total	22,270.6	340,000	2,978.4	100.0	196,460	1,721	20.4

Source: Nesteruk, 1963, pp 41-42.

The low cost/benefit ratios in the European sites mean that future hydropower developments must take place in Central Asia and Siberia. Table 3-7 shows the distribution of hydropower resources by republic. The majority is found in the RSFSR and Central Asia, with very little in the western republics.

Table 3-7

Hydropower resources of the USSR (1956)

Republic	Area, thousand km^2	Power potential			Specific power potential, kwhr/km^2 of land area
		Mw	billion kwhr	% of total	
RSFSR	16,922.0	248,125	2,173.5	73.0	128.4
Tadzhik SSR	142.6	26,845	235.2	7.9	1,649.1
Kirghiz SSR	196.9	15,224	133.4	4.5	677.3
Kazakh SSR	2,753 8	15,063	131.9	4.4	47.9
Georgian SSR	76.2	11,116	97.4	3.3	1,277.9
Uzbek SSR	407.5	7,137	62.5	2.1	153.4
Ukrainian SSR	576.6	5,046	44.2	1.5	76.6
Azerbaidzhan SSR ..	85.7	3,828	33.5	1.1	391.3
Turkmen SSR	484.8	2,702	23.7	0.8	48.8
Armenian SSR	29.8	1,679	14.7	0.5	493.6
Karelian SSR ...	178.5	1,118	9.8	0.3	54.9
Byelorussian SSR ..	207.6	636	5.6	0.2	26.8
Latvian SSR	64.5	611	5.4	0.2	83.0
Lithuanian SSR ...	65.2	436	3.8	0.1	58.6
Moldavian SSR ...	33.8	366	3.2	0.1	95.2
Estonian SSR	45.1	68	0.6	0.1	13.2
USSR	22,270.6	340,000	2,978.4	100.0	133.7

Source: Nesteruk, 1963, p 40.

The RSFSR possesses 73 percent of all hydropower potential, measured in terms of geologic and climatic conditions, 62.5 percent of the total is located in Siberia. Many sites and great portions of the geologic potential are unusable because of low head, low flow, or other conditions which make the construction of hydroelectric installations unfeasible. However, in world terms, the

USSR has great reserves of usable hydropower which could assist in the development of Siberia.

Hydropower Development as a Fuel Substitution Alternative

The Soviet energy reserves (coal, oil, and natural gas) in the European part of the USSR are presently being depleted or are losing their economic competitiveness through higher extraction costs (Tables 2-8 to 2-17). This trend is sure to increase as the demands for energy expand in the European part of the country and as the reserves fall lower. As the extraction costs in the European USSR increase, the comparable prices/costs for Siberian energy resources become more economically competetive, even when the additional transportation costs are included. The economic competitiveness is especially true for hydroelectricity. The unconverted output of hydropower stations is electricity, which when transmitted by wire, is less costly in labor and capital investment than the solid or liquid forms of energy like coal and oil (Figure 3-4) when evaluated in standard fuel ton equivalents.

The power generated at hydroelectric stations can be equated to coal, oil, natural gas, and other energy forms through conversion into standard fuel ton equivalents. The conversion to standard fuel (Table 3-8) of hydropower results in equivalence at 2898.55 kwhr per 1.0 ton of

Table 3-8

Energy Conversion Values

		SFT/SFE
Crude oil	1 ton =	1.430 tons
Natural gas	1,000 m^3 =	1.190 tons
Coal (hard)	1 ton =	0.718 tons
Coal (brown)	1 ton =	0.2 to 0.4 tons (depending on quality)
Peat	1 ton =	0.325 tons
Oil Shale	1 ton =	0.325 tons
Firewood	1 ton =	0.249 tons
Electricity	1 kwhr =	345 grams
	2898.55 kwhr =	1.0 tons

Other Conversions:

Crude oil 1.0 ton = 6.6 to 8.0 barrels (depending on specific gravity)

Note:

Soviet energy statistics as well as many international energy data sources are normally recorded in terms of tons of standard fuel equivalent or standard fuel tons (SFE/SFT). Standard fuel is defined as that containing 7,000 calories per kilogram or 7,000,000 calories per ton. The conversion used by Soviet statisticians for basic fuels are as given above (Equivalents in standard fuel).

standard fuel. Through this conversion it is possible to convert the output of various hydroelectric stations to the production levels of coal or oil fields. Thus Table 3-9 equates the output of Krasnoyarsk hydroelectric station, with an output of 6,000 megawatts to other energy production methods.

Table 3-9

Energy Production Equivalents to the 6,000 MW Output at Krasnoyarsk HES

HES	Other Energy Forms
	2070 tons of standard fuel/hour
	2883 tons of hard coal/hour
	8280 tons of brown coal/hour
6,000 MW	1447 tons of oil/hour
	10113 barrels of oil/hour
	1739496 cubic meters of gas/hour
	6369 tons of peat/hour
	6369 tons of oil shale/hour
	8313 tons of firewood/hour

When these data are extrapolated over the period of a year the figures become significant in the energy balance. Krasnoyarsk HES alone provides the same amount of electricity as would be rendered by the thermal conversion of 18,000,000 tons of standard fuel or 88,763,995.3 barrels of oil.

When the installed hydroelectric generation capacity of the USSR is thought of in fuel equivalence terms, the economic realities of hydropower loom larger than is normally assessed in the Soviet energy balance. Table 3-10 shows the comparison of hydropower (water) reserves to coal and other fuel reserves. The comparison of exploit-

Table 3-10

Soviet Fuel Reserves

	Geological (theoretical) reserves		Exploitable reserves according to categories A+ B+ C	
	billion tons**	%	billion tons**	%
1. Fuel	8,635	81.8	209.0	30.3
Coal	8,500	80.5	200.0	29.0
Other resources	135	1.3	9.0	1.3
2. Water	1,920 *	18.2	480 *	69.7
Total	10,555	100	689	100

* Conversion of water resources into unit fuel is by the UNO method, which assumes that these resources are naturally replenished over a period of 1000 years. One kwhr is taken equivalent to 0.4 kg of unit fuel.

** [Unit fuel.]

Source: Neporozhnii, 1965, p 22.

able reserves is where hydropower, as a long range source of energy, is superior, containing 69.7 per cent of all exploitable fuels of the USSR.

Cost Comparison Between Siberian Coal and Hydropower

At present the solid fuels of coal, oil and natural gas are being shipped from Siberia to the European part of the USSR. Tables 2-8 to 2-17 show the costs of these fossil fuel extraction and transportation to the central industri-

al core of the USSR. The question which must be answered if hydropower from Siberia is to have a real effect on the national Soviet energy balance is: Can Hydropower from Siberia economically replace the fossil fuel energy sources which are presently being used?

Figure 3-4 uses the fuel costs from Chapter II (Tables 2-8 to 2-17) and a base price of 0.025 to 0.05 kopecks per kilowatt-hour for power produced on the Angara/Yenisey Cascade (Neporozhnii, 1965, p 80) to provide an estimate of comparable costs. These costs provide an example which can be used to determine the feasibility or cost/benefit of replacing open-cast coal from the Kuzbas, at 17.6 rubles per ton of standard fuel equivalent delivered, with electricity from the Krasnoyarsk HES delivered in Moscow. It is approximately 3200 kilometers from the Kuzbas to Moscow and 3500 kilometers from Krasnoyarsk HES to Moscow. The example does not provide for the conversion and additional costs of converting the Kuzbas coal into electricity at one of Moscow's thermal power stations.

The exercise in Figure 3-4, using available figures, shows the cost of electricity delivered in Moscow from Krasnoyarsk substantially cheaper than coal from Western Siberia. These costs also compare favorably with natural gas from the Tyumen fields at 13.4 rubles per SFT (Table 2-15) and oil at 8.4 rubles per SFT (Table 2-12).

Table 3-11

Load Capacity, Transmission Distances and Cost of Direct Current Lines

System voltage	No. of cond. and dia. per pole	Normal rating per circuit	Transmission distance for 10% voltage drop at normal rating	Cost of lines per circuit		Specific transmission cost in £/MW/km for two values of selected loads			
kV	no x mm	MW	km	£/km Monopolar	£/km Bipolar	50 MW Monopolar	50 MW Bipolar	100 MW Monopolar	100 MW Bipolar
± 125	1x15	60	200	5340	3290	237	186	297*	272*
	1x20	80	260	5720	3670	199	149	192*	166*
	1x25	110	290	6580	4290	200	143	158	129
	1x31	150	330	8080	5410	224	158	149	116
						200 MW		400 MW	
± 250	1x31	300	660	8820	5870	79	61	79*	70*
	1x37.5	390	760	11180	7460	86	63	69	58
	1x45	480	860	13680	9510	96	71	66	53
	1x50	560	940	15780	11200	107	79	68	54
	1x56	640	1000	18400	13100	122	89	73	56
						750 MW		1500 MW	
± 375	2x32.5	960	1030	14040	10600	42	36	52*	49*
	2x37.5	1160	1150	16400	12500	41	35	43*	40*
	2x45	1460	1290	20600	16200	44	37	37	34
	2x50	1670	1400	24000	18750	48	39	36	32
	2x56	1920	1500	28500	22100	54	37	37	31
						1500 MW		3000 MW	
± 500	2x45	1940	1720	22400	17550	30	26	33*	31*
	2x50	2230	1870	26100	20100	31	26	30*	29*
	2x56	2560	2000	30100	23600	32	27	28*	25*
	3x45	2910	1720	28200	22750	31	26	27	25
	3x50	3340	1870	32900	26600	33	28	26	23
	3x56	3840	2000	38200	31350	36	31	26	23
	4x50	4450	1870	39000	32650	38	33	25	23
	2x50E	1990	1670	17700	13050	26	22	32*	30*
	3x50E	2990	1670	22000	17450	26	22	25	23
	4x50E	3980	1670	26000	20900	27	23	22	20
						4000 MW		7000 MW	
± 750	3x56	5750	3000	43400	38550	19	18	19*	18*
	4x56	7670	3000	54000	48650	21	19	17	16
	5x56	9590	3000	62300	56400	23	21	17	16
	6x56	11510	3000	70200	64150	25	23	17	16
						7500 MW		15000 MW	
± 1000	6x37.5	9260	3060	47100	39400	14	13	18*	18*
	6x50	13340	4000	67100	59200	15	14	14*	13*
	6x56	15340	4000	77800	69350	16	15	13	12
	7x56	17900	4000	90600	79000	18	16	13	12
	8x56	20460	4000	99000	87150	19	17	13	12

Source: Dey, P. and G. Orawski. "Optimization of Direct Overhead Transmission Lines," <u>IEE International Conference on High Voltage DC and/or AC Power Transmission</u>. London: M. W. Bailey & Co., Ltd. 1974, p 190.

Figure 3-4

Siberian Coal and Hydroelectricity Cost Comparison

Coal = 17.6 Rubles delivered in Moscow per SFT (Table 2-9)

Hydroelectricity=

a) Using a ±1000 kv-dc transmission line with a 31 year life would cost (using data from Table 3-11):

X = ruble/km x distance(km) / (kilowatt load/hr) x life

= 18 rubles/km x 3500 km / 1000 kw/hr x 365 x 24x 31

= 0.0002319 rubles per kwhr delivered in blocs of 15000 MW loads

b) Add to the above delivery cost a 0.0004 rubles/kwhr production cost (estimated average cost at HES in Siberia):

X = production costs + transmission costs

= 0.0004 rubles + 0.00023 rubles

= 0.00063 rubles/kwhr delivered

c) The average delivered cost must be converted to standard fuel tons from kilowatt-hours

X = delivered cost/kwhr x kwhr/standard fuel ton

= 0.0063 rubles/kwhr x 2898.55 kwhr/SFT

= 1.821 rubles/SFT delivered

d) A 10 percent line loss in transmission must be assumed:

X = cost delivered + 10 percent delivered cost

= 1.821 rubles/SFT + .1821 rubles/SFT

= 2.0031 rubles/SFT delivered in Moscow.

Soviet Electricity Production

If the computations and data used in Figure 3-4 are correct, then one must ask why this system has not been used in the past. A quick answer must suffice; the technology of the past would not allow this form or magnitude in the transmission of electricity, and the economies of scale for power transfer and consumption were not available.

The Soviets have always been dedicated to the electrification of the nation since Lenin created GOELRO in 1920 (Schopflin, 1970, p 372). Prior to the Soviet period only 2 per cent of Russian electricity was provided through hydro power. The Soviet era has seen this proportion rise ten-fold by 1958 to over 20 per cent (Jackson, 1971, p 20) and it remains almost at that level in 1970's.

Since 1955 the Siberian portion of Soviet electricity generated through hydropower has increased from zero to 36.3 percent (Table 3-12). The Siberian component is expected to continue to increase even more according to the Tenth Five-year Plan (1976-1980) (Table 2-1).

Table 3-12
Electric Power Production in Siberia (billion-kwhr)

Location	1940	1945	1950	1955	1960	1965	1970	1974
West Siberia	1.8	4.0	5.9	11.7	23	35	44	63
Hydro					1.6	1.7	2.1	
East Siberia	0.65	1.1	2.3	4.8	16	43	74	96
Hydro					3.7	18.3	42.4	
Far East	0.68	1.0	2.1	3.5	5.3	9.3	14	21
Hydro							0.6	
Total Siberia	3.2	6.1	10.3	20.0	44	87	132	180
Hydro					5.3	20	45.1	

Source: Shabad, 1977, p 29.

Raw Material Processing

The Tenth Five-year Plan's emphasis on using Siberia primarily as a source of raw materials has increased feasibility when the economics of transportation and the availability of cheap power are considered. The locations of Siberian ore and mineral extraction sites are obviously fixed, but the costs of transporting the extracted materials can be changed without a quantum level of additional investment. The primary refining and initial processing of many Siberian resources can be accomplished at the point of extraction, which would greatly reduce the bulk of materials being transported, thus requiring a lower level of investment in transport networks. A secondary consideration is the availability of low cost power from the large Siberian hydroelectric stations and the proposed thermal power generation plants to be located in the immense Siberian coal basins. Such capacity can support energy intensive plants for the processing of raw materials where a reduction in initial bulk is required.

Technological Infusions

The infusion of technology into the Siberian environment has long been noticable at the hydroelectric sites where very high levels of hydroelectric output (in the 2,500 to 6,400 MW range) are obtained. The same degree of

automation and technological infusion is underway at the huge coal-fired power generation complexes at Kansk-Achinsk in Eastern Siberia. The technological infusion trend will most likely continue in the other energy resource industries and in future mining, lumbering and primary sector Siberian industries.

Siberian Development Nodes

The Soviet need for an expanded industrial base and the dispersion of its strategic industries led to the initial expansion of production bases in Siberia prior to and during World War II. After the war this process continued with large scale works led by the enormous constructions at the Bratsk and Krasnoyarsk hydroelectric sites. The recent developments in Siberia have followed a fairly specific pattern based on earlier Soviet experiences. Such development entails first designation of a large energy production site located to take full advantage of the natural hydraulic forces of a large stream or extensive coal basin. Then this locational decision is heavily affected by the local deposits of needed natural resources.

After a site has been designated for the industrial node, construction then begins at the site to develop the energy supply plant as well as the industries which are to use the surplus power. Concurrently the complex is linked to the national transportation network by roads, railroads,

waterways and airports to permit the greatest degree of accessibility and to provide for the import and export of processed goods and raw materials. Finally, the needed infrastructure to house the workers and provide them the needed amenities as an incentive to remain in the isolated locations are built as required (Shabad and Mote, 1977, p 84)

The idea of a modular, almost self-contained industrial site is not new to economic expansion plans in isolated areas. Its introduction into the Siberian environment as the economic basis for development was very logical. These industrial complexes can readily be compared to the turn-of-the-century 'company towns' found in the isolated mining-frontier areas of the United States. These sites have their own stores, movies, schools, and recreation areas to meet the needs of the resident workers.

This model for Siberian development has not only been associated with hydroelectric sites, but also with the oil and gas development in the Ob basin (Western Siberian Complex) and at older sites like Norilsk for the production of copper and nickel (Shabad and Mote, 1977, p 33). Soviet planners have proposed many future development complexes (Table 3-13). The next industrial nodes to be initiated will probably be along the Baikal-Amur Mainline. Each of these complexes will be associated with an energy production facility (hydro or thermal) with primary and secondary industries utilizing the available energy to process and extract the local Siberian resources.

Table 3-13

Existing and Proposed Siberian Development Nodes

Name and Location	Energy Source and Industries
Middle Angara Irkutsk Oblast Angara River (operational)	Bratsk HES, capacity 4,500 MW Ust-Ilimsk HES, capacity 4,320 MW Functions: Power Production Sawmilling Pulpwood production Iron ore benefaction Aluminum reduction Copper smelting (Udokan ores)
Lower Angara Irkutsk Oblast Angara River (under construction)	Boguchany HES, capacity 4,000 MW Functions: Wood processing Copper smelting (Udokan ores)
Sayan Sayanogorsk Yenisey River (under construction)	Sayan HES, capacity 6,400 MW Functions: Power production Heavy metallurgy Nonferrous metallurgy Heavy machine building Aluminum reduction
Upper Yenisey Krasnoyarsk Yenisey River (operational)	Krasnoyarsk HES, capacity 6,000 MW Functions: Paper Power production Aluminum reduction (nephelinite) Wood processing Heavy equipment manufacturing

(continued)

(Table 3-13, continued)

Middle Yenisey Confluence of Angara and Yenisey Rivers (planned)	Osinovo HES, capacity n/a Stoney Tunguska HES, capacity n/a Functions: Wood processing (largest logging operation in USSR planned) Lead and zinc smelting
North Yenisey Norilsk Yenisey River (operational)	Khantayka River HES, capacity 441 MW Kureyka River HES, capacity 500 MW Thermal (Messoyakha natural gas) Thermal (local coal) Functions: Mining and smelting copper cobalt nickel platinum group metals
Middle Ob Tyumen, Tomsk, Omsk, and Novosibirsk Oblasts (operational)	Surgut thermal #1, capacity 1,200 MW Surgut thermal #2, capacity 1,200 MW Functions: Oil production Natural gas production Coal mining Peat mining
North Baikal Buryat ASSR Vitim River (under construction)	Mok HES, capacity 1,000 MW Functions: Power production Mining Asbestos Nonferrous metals Precious metals
Upper Lena Irkutsk Oblast Lena River Kibal Chich (planned)	Shorokhovo HES, capacity n/a (Kirenga River) Upper Lena HES, capacity n/a (Lena River) Thermal power, capacity n/a (South Yakutian coal)

(continued)

(Table 3-13, continued)

Upper Lena (continued)	Functions: Power production Wood processing Petrochemicals (based on the availability of fossil fuels)
Bodaybo Northeast Irkutsk Oblast (expansion planned)	Mamakam HES, capacity n/a (to be expanded) Functions: Power production Lena goldfield mining Nonferrous mining and reduction
North Chita North Chita Udokan (planned)	Initial power from local thermal plants and then connection to the Central Siberian Grid Functions: Mining (Udokan copper ores)
South Yakutia South Yakutia (under construction)	Neryungri Thermal, capacity 2,000 MW (based on local coal) Functions: Mining and concentration of iron ores Coal extraction Nonferrous metallurgy Mining precious metals Coke chemical industry Mineral fertilizers Metal fabrication
West Amur Western part of Amur Oblast (under construction)	Zeya HES, capacity 1290 MW Functions: Sawmilling (at Zeya wood processing complex) Mining (gold) Agriculture Power production (to electrify BAM Railroad)

(continued)

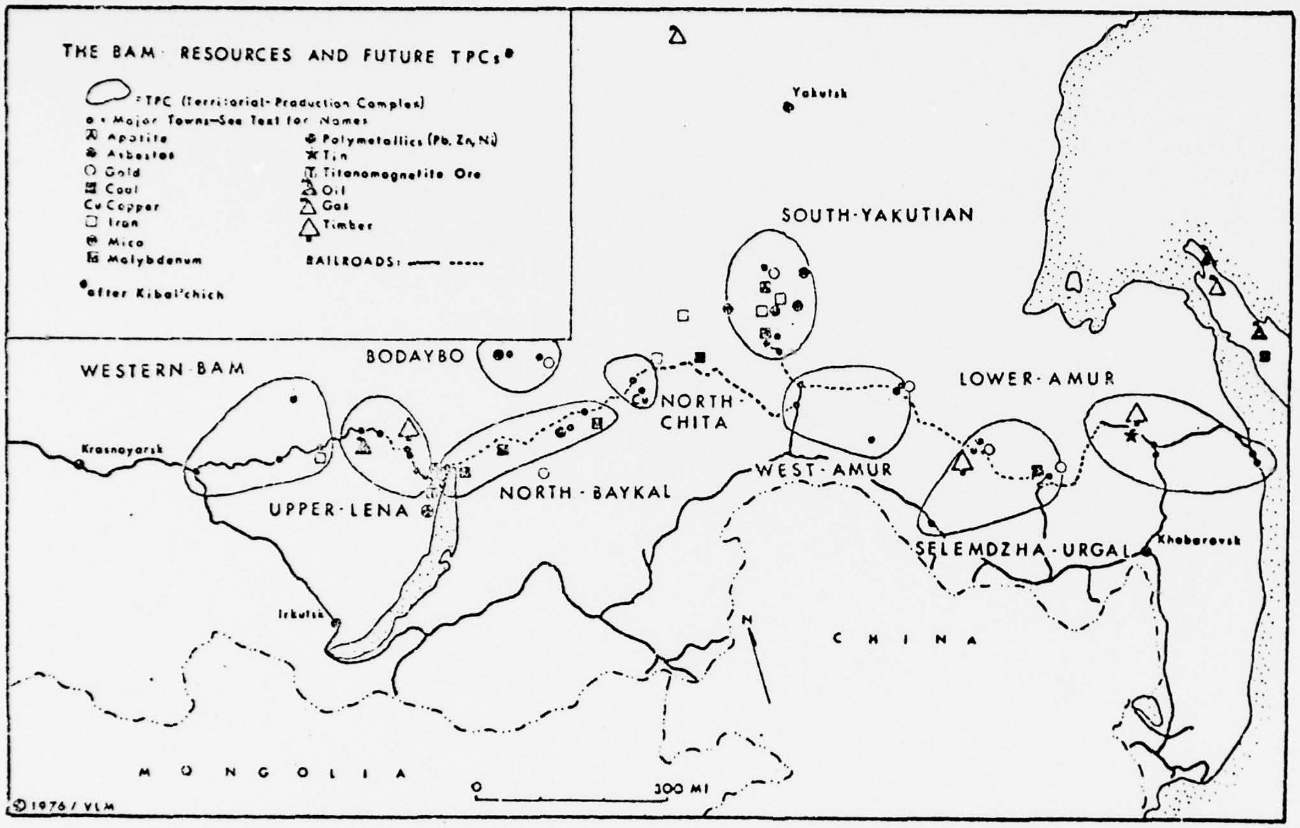
(Table 3-13, continued)

Selemdzha-Urgal Eastern part of Amur Oblast and western part of Khabarovsk Kray (under construction)	Talakan HES, capacity 2,000 MW (Bureya River) Functions: Coking coal production Wood processing Sawmilling Mining Precious metals Nonferrous metals
Lower Amur Western part of Khabarovsk Kray (planned)	Thermal power from imported Yakutian coal Functions: Wood processing Mining Tin Gold Steel production Aluminum reduction Manufacturing transportation equipment Fertilizer production Petrochemical refining

Sources: Connolly, 1975, pp 61-90.
Shabad and Mote, 1977, pp 23-35, 50-53, 84-87, 150-161.
Shabad, "News Notes", Sov Geog, 1975-1978.

Figure 3-5

Industrial Development Nodes in the Baikal-Amur Mainline Area of Influence



Source: Shabad and Mote, 1977, p 82.

BAM Resource Expansions

The construction of the Baikal-Amur Mainline (BAM) will open new regions of Siberia to economic resource exploitation. The construction sites, as well as major portions of the railroad, will be electrified by energy produced at the Siberian hydropower stations. The Bratsk and Krasnoyarsk HES provide power to the railroad at the western end and the Zeya HES is scheduled to electrify the line at the eastern end (Figure 3-5). The opening of this part of Siberia could provide expanded possibilities for Soviet exports to the Pacific rim nations. The BAM will afford access to the South Yakutian coal basin from which coking coal is to be shipped to Japan at the rate of 5-million tons per year for the next 20 years. The high potential for hydroelectricity in Siberia could also mean a high level of energy intensive light metallurgy as new HES sites are built on the rivers in eastern Siberia (Zeya, Upper Lena, Amur) in the vicinity of the BAM Railroad. Present plans propose to construct some 4,000 miles of high-voltage electrical transmission lines in the BAM area to support not only the railroad, but also the mining and forest products development complexes (Shabad and Mote, 1977, pp 80-90). The total Soviet development proposals appear to be aimed at increasing the Soviet element in Pacific rim trading activity.

Siberian Labor Problems

Past Soviet experiences have led planners to the conclusion that the most feasible method to exploit a region was to 'populate and industrialize'. This method was used in the Urals, south west Siberia, and Central Asia. Skilled Russian workers were required to assist in the industrialization phase, then remaining to maintain the industrial plants in operation at high levels of efficiency. The Russian volunteers who helped initiate these projects settled into the region. This process has often been termed 'Russification'.

The modern Russification of Siberia appears to be a different matter. The harsh climate of Siberia, as well as the lack of amenities compared with the western regions of the USSR have had a profound effect on the vast majority of the recent Russian immigrants to Western and Eastern Siberia. The latter were attracted by wage increments, the promise of longer vacations, and assured housing; inducements to offset the more austere conditions of Siberia. These inducements brought immigrants to Siberia, but could not retain them.

Population

Siberia has not had an absolute decline in population, because local natural increase has replaced all emigration losses. Siberia has had low growth and slight losses in its various sections in the past 40 years (Table 3-14).

Table 3-14

Population of Siberian Administrative Divisions (1939-75)
(in thousands)

	1939 census	*1959 census*	*1970 census*	*1976 estimate*
West Siberia	8,928	11,251	12,109	12,503
Tyumen' Oblast proper	850	906	1,055	1,085
Khanty-Mansi National Okrug	93	124	271	425
Yamal-Nenets National Okrug	48	62	80	126
Omsk Oblast	1,390	1,645	1.824	1,898
Novosibirsk Oblast	1,861	2,299	2.505	2,559
Altay Kray proper	2,225	2,525	2.502	2,474
Gorno-Altay Autonomous Oblast	162	157	168	169
Kemerovo Oblast	1,654	2,786	2.918	2,932
Tomsk Oblast	643	747	786	835
East Siberia	4,771	6,473	7.463	7,905
Krasnoyarsk Kray proper	1,659	2,160	2.465	2,549
Khakass Autonomous Oblast	275	411	446	474
Taymyr National Okrug	15	33	38	43
Evenki National Okrug	10	11	13	14
Tuva ASSR*	–	172	231	253
Irkutsk Oblast	1.303	1,976	2.313	2.492
Buryat ASSR	546	673	812	865
Chita Oblast	963	1.037	1.145	1,215
Far East		4,834	5.781	6,579
Amur Oblast	634	717	793	901
Yakut ASSR	414	487	664	779
Khabarovsk Kray	657	1.142	1.346	1,514
Maritime Kray	888	1.381	1.721	1.933
Sakhalin Oblast*	100	649	616	662
Kamchatka Oblast proper	86	193	287	323
Koryak National Okrug	23	28	31	34
Magadan Oblast proper	151	189	251	308
Chukchi National Okrug	22	47	101	125

*Tuva was not in USSR in 1939; Sakhalin included only the northern part in 1939.

Source: Shabad and Mote, 1977, p 26.

A cursory review of Siberian population data does not tell the whole Siberian demographic story. An analysis of the internal migration patterns as well as external

migration trends provides a new perspective of Siberian labor problems. A pattern often referred to as the 'flight of labor' exists. This trend consists of a loss of the skilled and trained personnel who can operate the technologically advanced and complex machines needed to exploit Siberian resources in an economic manner. Table 3-15 suggests the out migration from Siberia has come from the urban areas. While the 'flight of labor' can not be stated with any certainty, since no explicit data on this migration pattern are available, the assumption may be made due to the many comments concerning this trend in the Soviet press.

Table 3-15

Siberian Urban-Rural Population Distribution and Migration (1959–1970) (in thousands)

	Siberia as a Whole			*West Siberia*		
	Total	*Urban*	*Rural*	*Total*	*Urban*	*Rural*
1959 census	22558	12403	10155	11251	5724	5527
Natural increase	+3574	+1939	+1635	+1645	+826	+819
Net migration	–779	+1833	–2612	–787	+881	–1668
1970 census	25353	16175	9178	12109	7431	4678

	East Siberia			*Far East*		
	Total	*Urban*	*Rural*	*Total*	*Urban*	*Rural*
1959 census	6473	3414	3059	4834	3265	1569
Natural increase	+1125	+580	+545	+804	+533	+271
Net migration	–135	+618	–753	+143	+334	–191
1970 census	7463	4612	2851	5781	4132	1649

Source: Shabad and Mote, 1977, p. 25.

The out-migrants with skills are needed in the industrial development nodes to maintain efficient production and extraction levels. The associated rural to urban

migration has increased the total urban population, but has hidden the loss of skills of the out-migrants. Thus, the rural residents have tended to move into the local cities (2.6 million in the past decade) and the skilled urban residents have moved out of the region (Shabad and Mote, 1977, pp 24-25).

The data contained in Table 3-15 is difficult to interpret due to the changes of urban and rural classification of places. The change in classifications affects Siberia in particular due to its small population. An example is provided by Kamchatka Oblast:

> The urban population of Kamchatka Oblast proper, which had been rising at the rate of 9,000 to 13,000 a year in the early 1970's, jumped by 23,000 in 1974 because the large village of Atlasovo (with about 10,000 people) was raised from rural to urban status (Sallnow, 1977, p 690).

The total effect and magnitude of the Siberian population and labor migrations are hard to estimate, but in direct evidence shows it has driven Soviet planners to act to improve living conditions to retain a viable Siberian labor force.

Working and Living Conditions

The Soviet press has brought to light many facets of the unsatisfactory living and unfavorable working conditions in Siberia at the new and isolated development sites. Siberian development in the past has been mainly

located in south west Siberia with lesser developments along the route of the Trans-Siberian Railroad. Figure 3-6 shows the distribution of current development. Many of the new developments are north of the Trans-Siberian belt, in areas of almost no previous occupation and settlement. These locations have few amenities and only the most primitive of infrastructure. The opening of these areas causes hardship and deprivation to the first settlers and workers who are responsible for the initial construction of the new sites being carved out of the Siberian wilderness.

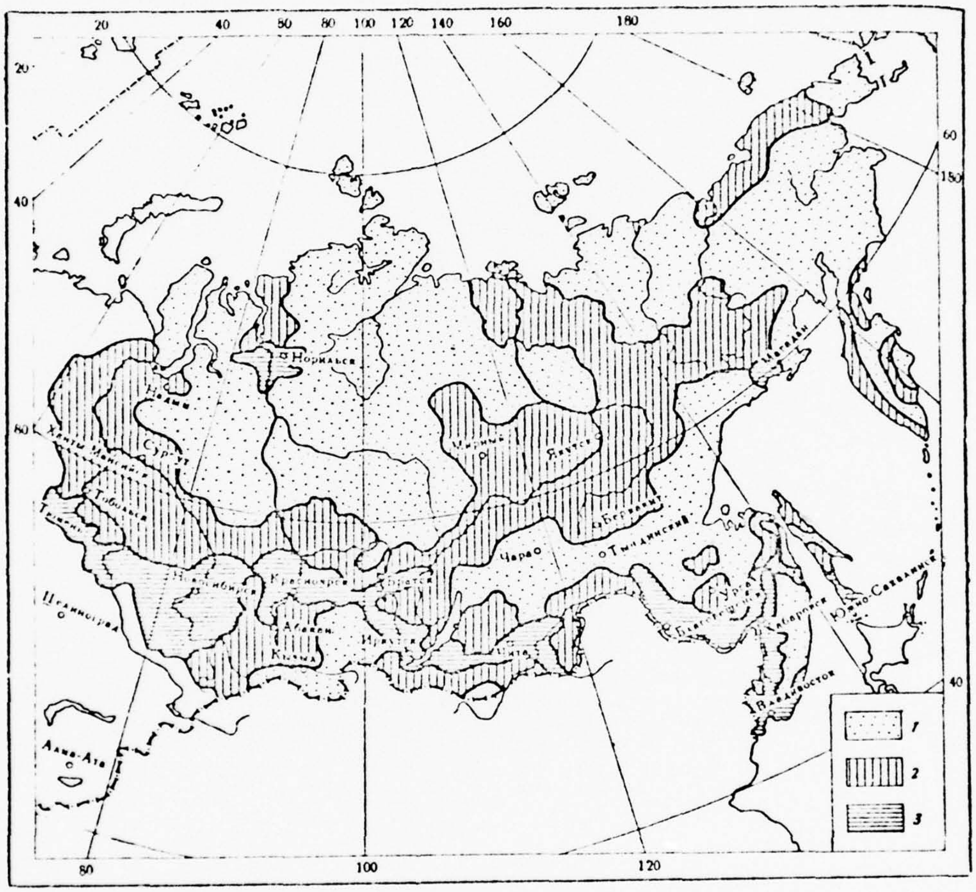
The conditions at the Sayan hydroelectric site are an example of the problems found at many remote construction sites. Connolly, a British author on Soviet Affairs describes these as follows:

> The 'living problem', which has plagued Siberian construction for years has also emerged at Sayan in 1971..... Questions of living-social-cultural construction arise with special acuteness in connection with the creation of the Sayan complex. The failure to provide living accommodations, children's institutions, shops, and schools for a number of new enterprises has retarded the completion of the production units and caused a great flight of labour (1975, p 86).

The problem of neglecting portions of the new industrial complexes is not a new phenomenon as it occurred at Bratsk, Irkutsk, Ust-Ilimsk, Krasnoyarsk, and at most other large Siberian construction sites. The real need for the early construction of worker facilities and amenities is based on the substantial problem of labor flight.

Figure 3-6

Economic Development Zones of Siberia and the Far East



Legend: 1 - sparse, insular development
2 - partial, selective development
3 - intensive, continuous development

Source: Pomus, 1976, p 542.

It may well be that the Soviet Ministry of Housing has not been properly included in the budgeting of funds for these projects at GOSPLAN levels, and thus has not been able to provide the needed infrastructure. This is a continuing problem that is not yet solved.

Since the first attempts at modern Siberian exploitation of hydropower, oil and natural gas, retention of a labor force has been a problem. Connolly has quoted a Siberian official on the problems involved in retaining a viable working force as follows:

> Retention of an indispensable corps of skilled and unskilled workers has presented the industry and government with formidable problems. The failure of the responsible Soviet authorities to solve these problems is reflected in the high level of departing workers. This 'flight of labour' not only disrupts production but is also causing great energy and financial losses to the State. It is variously reconned (sic) that it costs between 16,000 and 20,000 rubles to settle a worker family in the Tyumen Oblast. And these high costs have put some steam behind the move to mechanize production more rapidly. The reports of expert Soviet observers on the unbelievably bad housing conditions in the oil-gas fields, with the inevitable corollary that the situation must be radically improved if a stable labour force is to be created, have been common for nearly a decade now. Judging from the most recent comments, the position, though definitely improving, still remains unsatisfactory (1975, p 67).

The situation described above has caused thousands of workers to live in difficult conditions or leave for the western part of the USSR. It is estimated by Connolly that approximately 80 per cent of the immigrant workers leave areas of Siberia due to shortages of housing and normal living conditions. The incentive of higher pay will not hold workers on a permanent basis if other conditions are not satisfactory (Connolly, 1975, p 68). Many examples of these unsatisfactory conditions may be found at the

hydroelectric sites in Western Yakutia and on the Taymyr Penninsula. In both these locations temperatures may drop to -70°C in winter, which, when combined with gale winds across the tundra, prevent activity out-of-doors. The summers are humid, the earth thaws into mud, and there is no escape from the black flies and gnats.

The Soviets have attempted to correct the problems at their existing sites as planned funds and materials become available. Experience and time will probably make the construction of future complexes better planned, incorporating the facet of human engineering by providing both housing and worker amenities to the settlers.

The need for change is forced by the awakening concept of external costs and their effects on the economics of Soviet decision making. These costs have been discussed during the Ninth Five-year Plan (1971-1975). Kotliar, a Soviet economic spokesman, was quoted in the 1974 Soviet Review as stressing the costs of high labor turn-over rates in the Soviet economy. He estimates that a one per cent turn-over rate for labor in the RSFSR costs 117 million rubles. A comparison made by Kotliar (1974, p 37) shows a high annual turn-over rate in Siberia compared to other regions of the USSR. The lower labor disruption and associated lower costs in the Western regions is shown as follows: in Voronezh Oblast the Trikotazh Association reported an annual 6.4 per cent labor turn-over rate, while in the

Northwest the Murmansk area chemical plants reported an 8.6 per cent turn-over and the Murmansk Breziniakovskii Construction Trust reported a low 4.2 per cent labor turn-over. These rates are all very low when compared to the Siberian annual rates of 82 per cent at the Tomsk Manometer Plant, 91 per cent at the Ordzhonikidze Machine Building Plant in Western Siberia, while a staggering 112 per cent labor turn-over rate was reported at the Krasnoyarsk Promstroi Trust in Krasnoyarsk (Kotliar, Soviet Review, Summer 1974, p 37).

Another Soviet planner, Perevedentsev (as quoted by Sallnow, 1977, p 691) assesses the problem as follows:

> A high turnover of the labor force is due to higher prices for services, a weakly developed transport network and poorer facilities for vacations and recreation...... an assessment of the standard of living is made personally by millions of individuals, either consciously or unconsciously, and thus the outflow of people is an "unmistakable indicator of the lagging behind of a particular district in living standards." However, "It is not always a good idea to increase the monetary wages as this leads to the basic aim among migrants to save a certain sum of money and then leave the region, as the spending of that money elsewhere will give them much greater reward. This is known to apply to Siberia."

Sallnow recommends that the best method of reducing labor turn-over is to provide "greater investment in the infrastructure, so that the living standards of the people in these remoter areas is brought up to the standards of

the European part of the USSR." (Sallnow, 1977, p 698). The Norilsk complex in the Far North is an example of the high economic input costs of satisfactory development in a remote environmentally harsh area (estimated by Sallnow to be two or three times more costly than a similar complex in southern Siberia). Norilsk is a large nickel mining site in the northern part of Eastern Siberia with a population of 145,000. Pokshishevsky (1974, pp 275-276), the Soviet geographer, describes Norilsk as follows:

> Although situated in extremely rigorous climatic conditions it is a smoothly functioning urban organism with many modern many-storied apartment houses, schools, clubs, theaters, research institutes, hospitals, etc. The layout of the town is compact: all servicing establishments are situated very close to residential districts, reducing to the minimum the time people spend out of doors in bad weather. The layout also takes into account the frequent strong winds, and the pattern of the streets is such that they are screened from strong gusts and gales. Indoor gymnasiums, swimming pools and winter gardens in schools and clubs, a correct diet, quartz lamp treatment to make up for the shortage of ultra-violet rays, and other measures to offset the rigorous climatic conditions to which the human organism is subjected. The complex of health-building measures for the children of arctic towns is being elaborated with particular care.

The Norilsk-type complex is one example of Siberian development and such complexes are being constructed in several other remote regions. This method of development, however, is very expensive and requires not only large labor inputs, but also vast capital investment. The Soviet

Union does not have unlimited investment funds which can be diverted to develop the resources of Siberia. A less costly method of development, rather than providing the eastern regions with dense settlements and costly integrated communication networks, is presently being implemented. The scheme of development is to site industrial and extractive complexes in the vicinity of large resource deposits and energy sources. The technological infusion and automation of equipment then occurs. These infusions lower the required size of the labor force and thus reduce costs.

The high costs of moving workers to labor deficient areas is not always a suitable remedy to long term labor problems. A plan to use Siberiaks, who are acclimated to the Siberian environment, as the local work force, is required. The labor requirements must be kept to levels commensurate with the limited available Siberian manpower supply. It will thus also be necessary to provide training and education to the Siberiaks so that they can be properly used in the technologically complex and automated extraction of Siberian resources. As A. A. Mints (1976, p 20) has suggested:

> It has been increasingly realized that the movement of people through space is far more complex and less controllable in every respect than the movement of things, such as energy and materials.

Thus it appears that the long range Siberian development strategy is changing. This is reflected in the Tenth Five-year Plan and in the guidelines for the 1976-1990 Fifteen year Plan. These changes are due partly to the Siberian labor problems, but also because of an acknowledged and growing need for raw materials and energy to support the central industrial base in the European part of the USSR.

Chapter IV

"Cascade" Schemes for Siberia

The Communist Party of the Soviet Union has long backed the expansion of hydroelectric and multi-purpose dams. The most highly developed and extensive system presently in existence is that on the Volga River (Schopflin, 1970, p 372). This system has its roots in Lenin's original electrification plans. As is expected, the initial hydroelectric development was in the European region of the USSR due to its proximity with the industrially developed areas. It was not unti the mid-1950's that construction was begun on the first large Siberian hydroelectric stations.

Geographical isolation and lack of a local demand for electricity can readily explain the delayed development of Siberian hydro stations. The largest Siberian developments to date have been in the Angara/Yenisey basin, and no large dams have yet been constructed along the mainstream of either the Lena or the Amur (Connolly, 1975, p 78).

The Soviet regime presently is undertaking a program of research to find suitable sites along the remainder of the large Siberian rivers with the intention of establishing co-location of the possible hydroelectric sites and the development nodes for the extraction of natural resources in the interior of Siberia. In this manner the hydroelectric sites can provide the power

needed to assist in the development of the resources as well as lower the total manpower required to extract and process these materials during the exploitation period.

Extensive construction has taken place in the past 25 years (Table 4-1) within Siberia. These sites are now well established and are the basis for much of the Siberian economy.

Table 4-1

Major Hydroelectric Stations of Siberia

Name	*Location*	*River*	*Designed Capacity* (megawatt)	*Number of generating units* (megawatt)	*Construction dates* *Start*	*First unit*	*Last unit*
Novosibirsk	Novosibirsk	Ob'	400.4	7 x 57.2	1950	1957	1959
Irkutsk	Irkutsk	Angara	662.4	8 x 82.8	1950	1956	1958
Bratsk	Bratsk	Angara	4050	16 x 225* 2 x 250	1954	1961	1966
Krasnoyarsk	Divnogorsk	Yenisey	6000	12 x 500	1956	1967	1971
Ust -Ilim	Ust -Ilimsk	Angara	4320	18 x 240	1962	1974	(1978)
Sayan	Sayanogorsk	Yenisey	6400	10 x 640	1963	(1978)	
Boguchany	Koda	Angara	4000	12 x 340	1976	(1983)	
Vilyuy	Chernyshevskiy	Vilyuy	308	4 x 77	1960	1967	1969
Vilyuy	(second stage)		340	4 x 85	1972	1975	
Zeya	Zeya	Zeya	1290	6 x 215	1964	1975	
Bureya	Talakan	Bureya	2000	7 x 285	1976	(1983)	
Kolyma	Sinegor'ye	Kolyma	750		1970	(1980)	
Khantayka	Snezhnogorsk	Khantayka	441	7 x 63	1963	1970	1972
Kureyka	Svetlogorsk	Kureyka	500		1975	(1981)	

*The 225-megawatt units at Bratsk were being upgraded to 250 megawatts during the five-year plan 1976–80, raising the installed capacity to 4,500 megawatts.

Source: Shabad and Mote, 1977, p 30.

The majority of the Siberian hydropower sites are located at the edge of the Central Siberian Plateau. These locations are explained by the excellent physical geologic situations for hydropower sites. Many of the

upper river valleys, such as the Angara, contain large and deeply incised gorges which are combined with high rates of annual flow. This region is accessible under the present transportation network and, as these networks expand, other areas in the Soviet Far East and Northeastern Siberia can also be expected to be developed.

The development of each major Siberian river basin should be discussed separately. The following pages will cover the present and proposed developments for the Ob, Irtysh, Lena, Amur, Yenisey, and Angara rivers.

Ob/Irtysh Cascades

The most western of the great Siberian river basins is the Ob-Irtysh system. The area of this watershed is the largest of all Soviet river basins as it includes the West Siberian Lowland. The hydropotential of this basin is estimated to be 50-billion kilowatt-hours annually (Jackson, 1971,p 43). The combined runoff of the Ob-Irtysh river system is 394 cubic kilometers. This large runoff is of low hydroelectric generation value because the Ob has a drop, or head, of only 161 meters over its 5569 kilometer length (Nesteruk, 1963, p 160). Figures 4-1 and 4-2 portray the planned development of the Ob River. The proposed Lower Ob HES at Salekhard, Nizhne-Obskaya (5,000 to 6,000 MW), has been very controversial in the USSR, as it would make the Ob Sea if built. The Ob

Figure 4-1

Ob River Development Plan

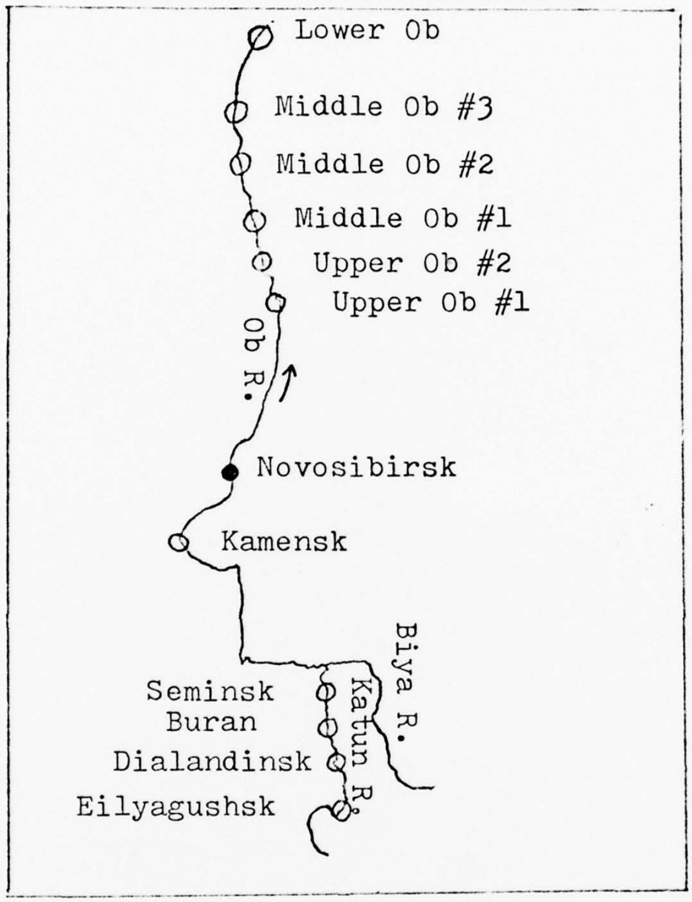
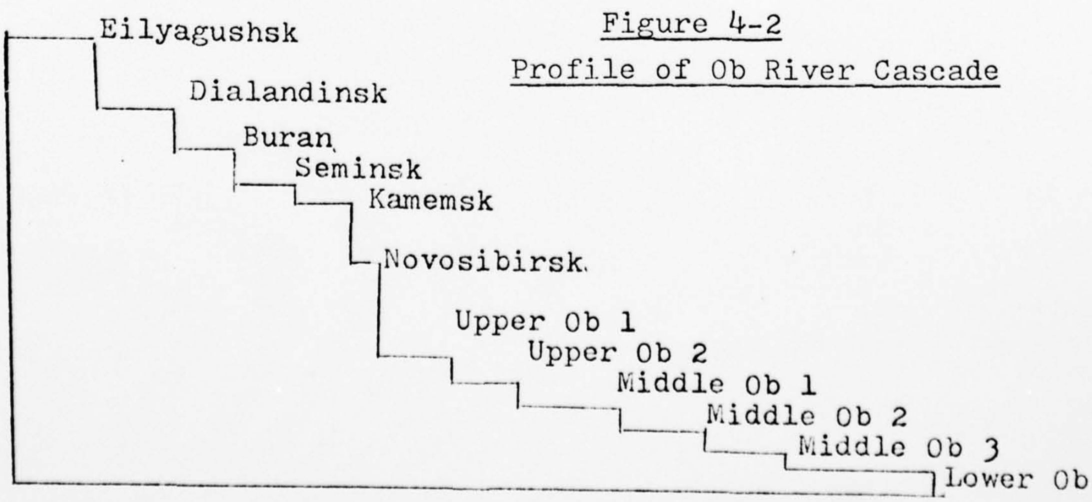


Figure 4-2

Profile of Ob River Cascade



Sea reservoir would have an area greater than 90,000 square kilometers, which is larger than the surface of Lake Baikal (Nesteruk, 1963, p 161). The area of inundation was planned for the region which now is known to contain the large West Siberian oil and natural gas fields. The Lower Ob dam is thus unlikely to be constructed in the near future.

The Irtysh River is the largest tributary of the Ob and has an estimated hydroelectric potential of 38-billion kilowatt-hours per year. A cascade of 13 hydroelectric dams is expected to be built. The largest dam is planned to be the Shulba HES in the Kazakhstan Lowland at the foot of the Altay Mountains. Nesteruk of the Soviet Academy of Sciences states that this flowage, as well as future water supplies from the Ob itself, should be used for irrigation in the Central Asian and Kazakh deserts. The electricity generated from the existing HES on the Irtysh and Ob Rivers is presently integrated into the Northern Kazakhstan and Central Siberian power grid networks.

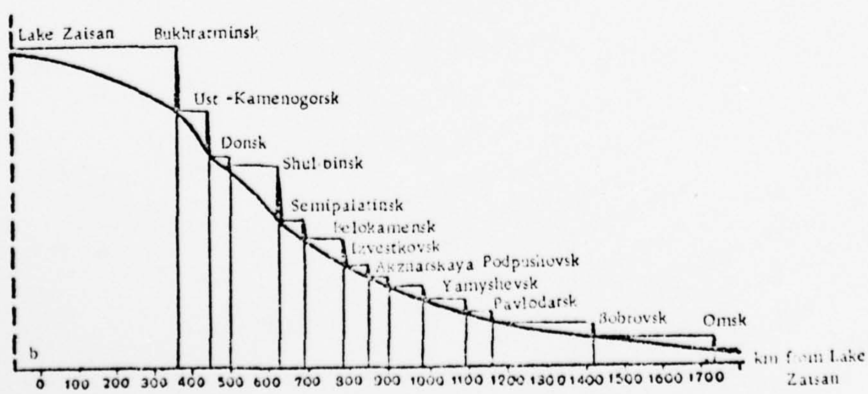
The power from both the Ob and the Irtysh (Figures 4-3 and 4-4) Cascades will provide local power for the development within the Ob Basin of Siberia and North Kazakhstan, with special emphasis on the electrification of the on-going oil and natural gas exploitation areas. The low head potentials in the region will not generate the large power loads as are expected for export from Eastern Siberia.

Figure 4-3

Irtysh River Development Plan

Figure 4-4

Profile of the Irtysh River Cascade



Source: Nesteruk, 1963, p 161.

The Lena Cascade

The Lena River, with the largest hydropower potential in the USSR, is almost totally located within the permafrost regions of northeastern Siberia. Little published Soviet planning of the Lena River is found in available sources. The Lena is the second largest river in the USSR with an annual runoff of approximately 438 cubic kilometers. The design and operation of hydroelectric plants in the region are still experimental due to the additional problems of hydraulic construction on permafrost surfaces. Two HES have been constructed on tributaries of the Lena; the Vilyui and Mamakan Rivers. No large construction on the Lena is expected to occur until the region is opened by railroads and roads in the late 1980's. Construction along some of the Lena's main tributaries may occur prior to that time. The tributary stream potential is large and valuable in hydropower generation capacity (Table 4-2).

Table 4-2

Hydropotential of the Lena and Its Tributaries

River	Potential (in megawatts)	Potential Annual Output (in billion kilowatt-hours)
Lena	18,358	161
Aldan	5,510	48
Vitim	5,425	48
Vilyui	2,424	21
Olekma	4,007	35

Source: Jackson, 1971, p 43.

In 1963 the Soviet Academy of Sciences published an overview of the Lena basin development plan (Figure 4-5).

Figure 4-5

Navigation and Hydroelectric Development of the Lena Basin

Source: Nesteruk, 1963, p 164.

The plan will not only provide hydropower for the entire Lena basin, but also provides a water transport network in the roadless Yakutian area. A viable transport network is necessary to import and export materials

which are needed at presently inaccessible development sites that are presently serviced only by airlift networks.

The largest proposed hydroelectric station in the USSR is planned at the Nizhne-Lena site. As the Lena River flows out of the Verkhoyansk Ridges the hydraulic conditions provide a capacity to power a 20-million kilowatt power station. This single power station is projected to provide an annual output of 100,000,000,000 kilowatt-hours (100-billion kwhr), or as much as the entire Soviet Union's output in 1951. The site is 2.3 kilometers wide and 25 meters deep. The scale of such a project is huge even by Soviet standards. The dam will create the Nizhne-Lena Sea which will be 1,500 kilometers long and cover 61,000 square kilometers (Sinedubsky, nd, pp 129-132).

The Amur Cascade

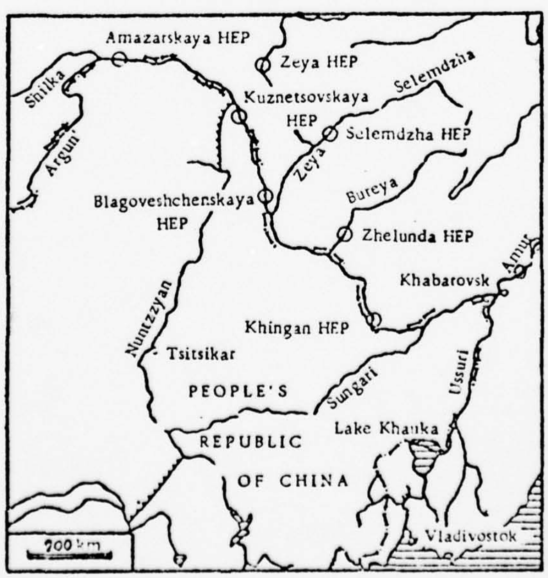
The Amur River is the largest of the Soviet rivers to flow into the Pacific Ocean. The Amur is often associated with large floods and erratic flow regimes. The hydroelectric stations planned along this river and its tributaries would not only generate electricity (estimated to economically provide 100-billion kwhr annually), but could also provide effective flood control to increase agricultural production in the lower Amur basin (Nesteruk, 1963, p 252). Construction on the Zeya

River, a Soviet tributary, is almost completed on a 1,290 MW HES. The power from this HES is being fed into the Far Eastern power grid and later is expected to support part of the industrial power requirements for the BAM development nodes (Shabad, 1977, p 275).

The full development of the Amur basin (Figures 4-6 and 4-7) will probably not occur until the USSR and the People's Republic of China conclude a lasting and firm agreement on their national boundaried. Approximately 46 per cent of the Amur catchment basin lies in the People's Republic of China. Proper river basin planning must include the Chinese tributaries as well as joint efforts on the mainstream of the Amur where the latter forms the international boundary.

Figure 4-6

Proposed Development of the Upper Amur Basin



Source: Nesteruk, 1963, p 253.

Figure 4-7

Proposed Development of the Lower Amur Basin

Source: Sokolov, 1964, p 520.

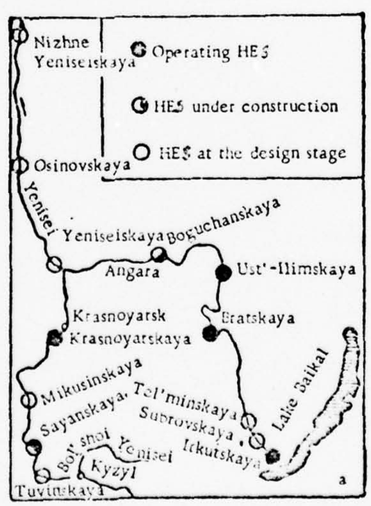
The Yenisey and the Angara Cascades

The Yenisey and the Angara Rivers are presently the most important elements in the hydroelectric development of Siberia. The true potential of these cascades, as in other Siberian river basins, lies not only in the electric power generated or improved waterways, but also in the amount of fossil fuels which will be consumed if

these great sources of energy are not fully developed. The Soviet Academy of Sciences (Nesteruk, 1963, pp 154-160) estimates that the Yenisey basin (Figures 4-8 and 4-9), with a power potential of 57-megawatts could produce over 300-billion kwhr annually. The Angara River (Figure 4-10) alone, with the most favorable power generation conditions, could provide approximately 70-billion kwhr annually from an installed capacity of 14-megawatts.

Figure 4-8

Proposed Development of the Yenisey Basin



After: Nesteruk, 1963, p 155.
(Updated to 1978)

Figure 4-9

Profile of the Yenisey Cascade

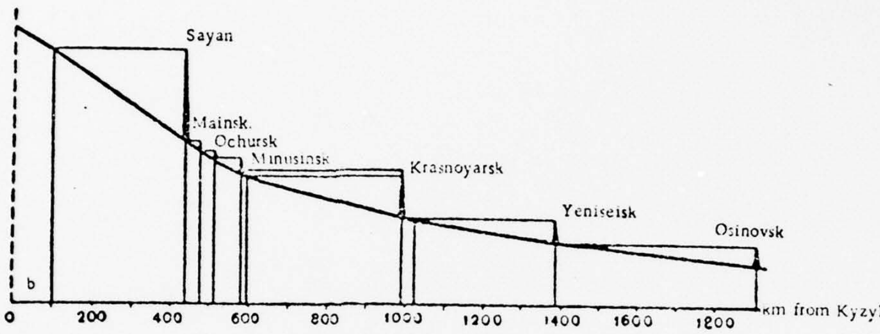
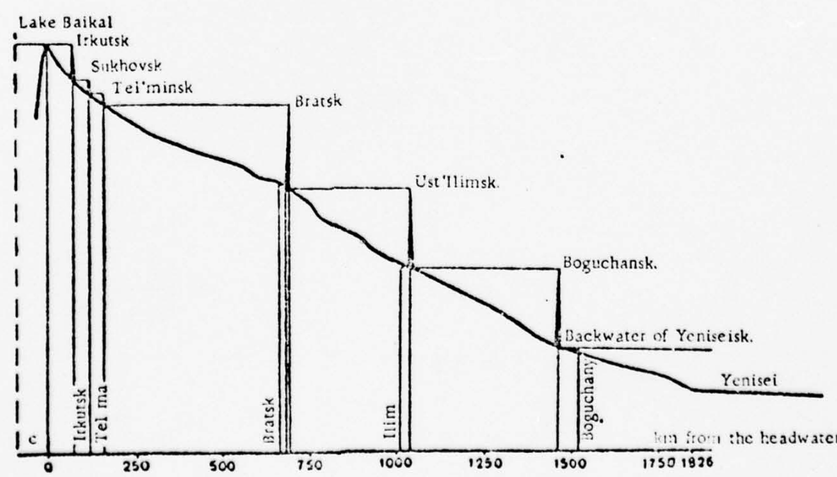


Figure 4-10

Profile of the Angara Cascade



Source: Nesteruk, 1963, p 155.

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Figure 4-9

Profile of the Yenisey Cascade

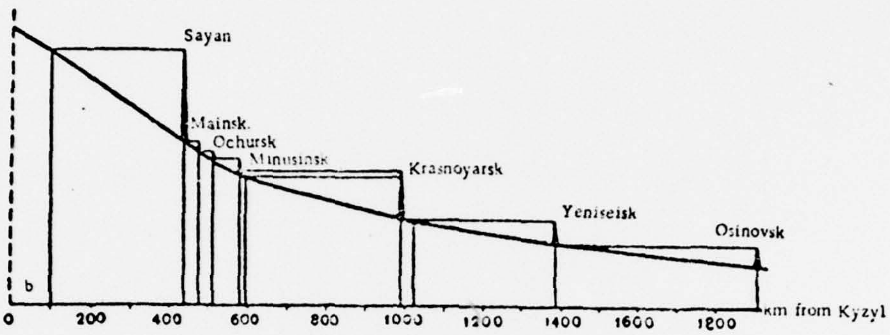
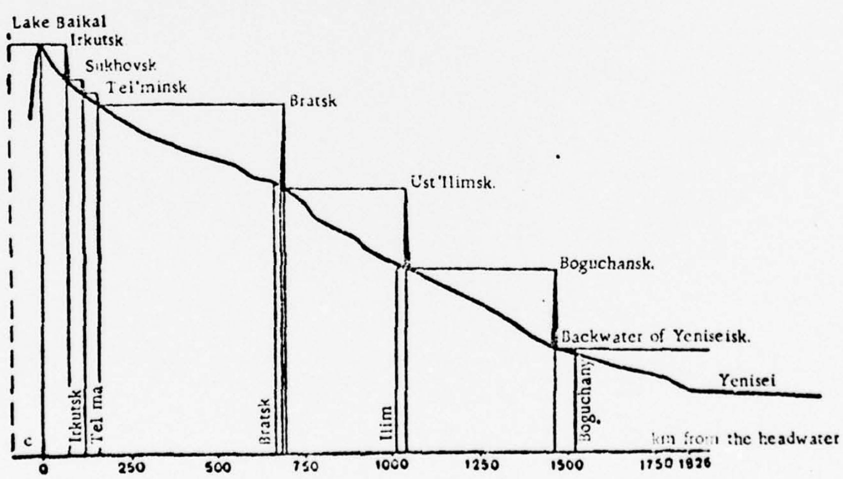


Figure 4-10

Profile of the Angara Cascade



Source: Nesteruk, 1963, p 155.

Grid Networks

The new extra-high-voltage transmission lines which have been built (500-kv and 750-kv) from the existing HES in East and West Siberia permit the flow of some portion of hydroelectricity to the Western regions of the USSR. As newer and larger capacity lines are built the true effect of these power sources will be observed. Under construction is a high-voltage network throughout the country to connect all the power sources into one integrated national grid. Construction began in January 1978 on a 1500-kv dc line to transmit power from the thermal plants at Ekibastuz and the Kuzbas to the central industrial base (Shabad, 1978, p 216). Eventually the HES sites in Western and Eastern Siberia will likewise be linked into the extra-high-voltage network. The 300-billion kwhr available annually from the Angara/Yenisey Cascade, as well as future Soviet Far Eastern power sources could begin to replace an estimated 103.5-million tons of standard fuel, or 413-million tons of brown coal of the quality being mined at Ekibastuz each year. The hydroelectricity could be fed into the same national power grid which receives the present preponderance of thermal power and thus save the USSR large amounts of fossil fuels for other uses.

The integration of the Soviet power grids at extra-high voltages could occur within the Eleventh Five-Year

Plan. Most of the hydroelectric plants on the Angara and Yenisey Cascades could be finished during that period while the Soviets concurrently complete the electrical integration of the Central Siberian Grid with extra-high-voltage direct current links into the western power grids of the USSR. The Far Eastern Region of the Lena and the Amur basins can be expected to join in a nationally linked grid network by the 1990's. Figures 4-11 and 4-12 display the current grid networks and areas of integration.

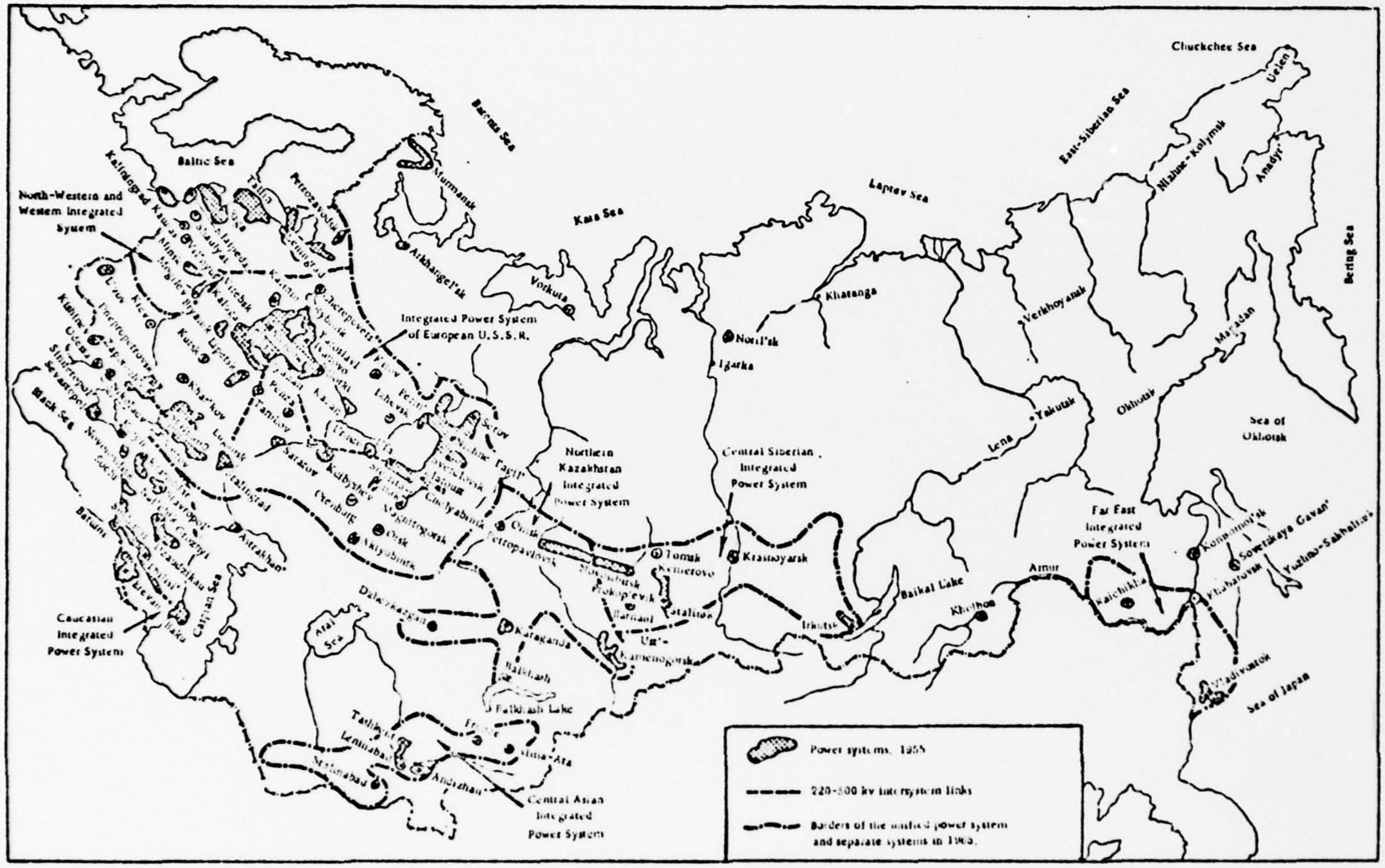
Since 1975, all grids, with the exception of the Far Eastern power grid, have been interlinked with 500-kv transmission lines (Elliot, 1974, p 224 and Shabad, 1976). Soviet planners expect that the next level of long distance national grid interlinkages will be in the 750-kv AC and 1500-kv DC transmission lines for high capacity loading and low transmission loss. Full descriptions and discussion concerning the proposed national power grid published recently have not been available to this student during research for this paper, though many of the benefits of such a grid have been discussed in available sources.

The major benefits of a national grid for the USSR could be best described in power economic terms:

a) <u>Peaking Power</u>: This will permit the USSR to use a smaller total nation-wide generation capacity to meet regional demands during hours of peak load. The USSR contains 11 time zones and a national grid could take

Figure 4-11

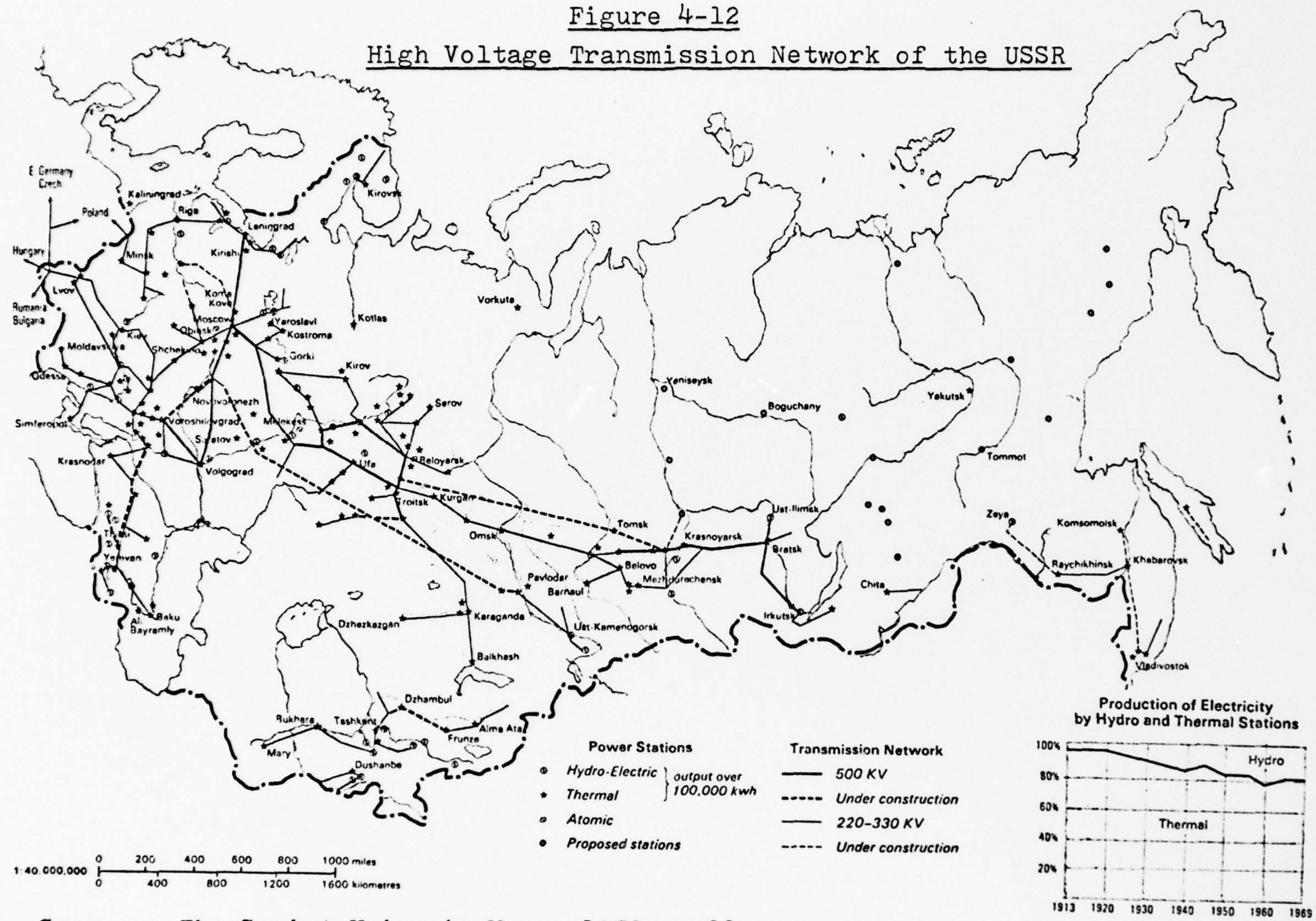
Integrated Power Grids of the Soviet Union



Source: Neporozhnii, 1965, p 33.

Figure 4-12

High Voltage Transmission Network of the USSR



Source: The Soviet Union in Maps, 1972, p 20.

from one region to another as the peak demand fluctuates across the country. This means that a lesser amount of power generation capacity would be needed compared to a situation where each region was forced to meet its own peak demands, then having surplus capacity the rest of each day.

b) Reserve Capacity: A unified nation grid would be able to supply power to widely separated regions which suffer power shortages or power failures, with less reserve capacity than that required for localized systems.

c) Inexpensive Transportation of Power: The transmission, by wire, of both low-cost hydropower and non-transportable coal reserves converted to electricity at the mineheads, affords an alternative to a large investment in transporting fossil fuels designated to be converted into electricity at other locations. However, it is known that much electricity is lost in transmission. The 1975 total Soviet line losses were 152-billion kwhr, and future transmission losses with greater transfers and longer distances are expected to be 194-billion kwhr in 1980 (Shabad, 1976, p 718). This amount is large, but compared to the energy costs of transporting equal amounts of other energy fuels to their places of utilization it offers great advantages.

These factors combine to suggest that a national grid network for the USSR would probably be the most economical and efficient method of meeting the long-term power needs

of the USSR, both on regional and on a national basis.

The Benefits of Hydropower

The benefits of a national grid system meet the national requirements and make the most efficient use of both the thermal and hydropower generation capacities. The low-cost Siberian hydropower justifies its transmission over long distances to the Western regions of the USSR. The Soviet regime is therefore justified in moving ahead with hydropower exploitation plans. Neporozhnii (1961, p 26) of the Soviet State Electrification and Energy Ministry has provided the best reasons for the priority given this development and the construction of hydroelectric power stations:

1. Electric power can be generated more economically from the extremely large water resources available in the USSR, than by use of thermal stations.

2. The non-uniform distribution of water and fuel resources means that hydroelectric power is the decisive factor in industrial development in a number of regions.

3. Apart from power generation, hydroelectric schemes can be devised to serve the needs of river transport, farming, fishing, and flood control.

4. Hydroelectric stations have certain advantages over thermal power stations. These are: The fact that water resources naturally replenish themselves, the high dependability of hydroelectric power stations in operation, irrespective of transport and other considerations, the high efficiency of labor utilization, the hydroelectric power stations exceptional reliability in handling peak loads, the clean working conditions in hydroelectric power stations, and the lack of atmospheric pollution.

Neporozhnii's arguments and the great savings which could occur in terms of the substitution of hydroelectricity for fossil fuels are the best reasons to advocate immediate expansion of hydropower generation facilities in the USSR. These arguments were valid in 1961, and still maintain their validity in the 1975-1980 technology framework. The future depletion rates of fossil fuel reserves and their increasing extraction costs could be reduced through the development of more hydroelectric stations. Water power is a renewable resource which can provide energy production for many years at low costs in labor and capital. This is the great economic potential of hydropower in the USSR.

Chapter V

Conclusions

Core-Periphery Relationship

The European part of the USSR, including the Urals, possessed an industrial base before the Soviet period began. European Russia has approximately 75 per cent of the population and over 75 per cent of the industrial infrastructure. The European part of the USSR is truly the industrial heartland of the Soviet Union. The economic inertia of capital investment within the central industrial region, combined with a stable workforce, comparatively moderate climate, and worker amenities, appears to be causing Soviet planners to think, on an all-Union economic basis, in terms of a classic core-periphery relationship between the European USSR and Siberia.

The European sector is deficient in many resources, chiefly energy. Siberia has a wealth of both mineral and energy resources. However, Siberia is relatively unpopulated, has few amenities, and a very harsh climate. The lack of modern infrastructure and worker amenities has had an adverse effect on establishing and maintaining a stable work force. Siberia is expected to be the source of the raw material and energy needed in the central industrial base. To meet the resource demands of Soviet industries, large amounts of both capital and technology must

be invested in Siberia. The lack of a large Siberian labor force necessitates extensive automation of equipment and the use of Siberiaks, Russians who, though adapted to the Siberian environment, must be trained to operate the complex machinery which will extract the resources. This program of capital and technologically intensive development could provide the central industrial base with coal, oil, natural gas, copper, nickel, forest products, and other needed materials.

Technology

The advent of new technologies to transport energy and other raw materials from Siberia to the central industrial base make it possible for Siberia to compliment the industrial core as a peripheral resource base. The construction of modern gas and oil pipelines permit additional expansion of the base area through the increased availability of these fuels and their low cost. The construction of extra-high voltage DC transmission lines will shortly bring 'coal by wire' from areas such as the West Siberian coal fields to assist in powering the central industrial base. This same technological infusion could expand to provide accessibility of Siberian resources outside the USSR.

Hydroelectric Development

The policy of constructing large hydroelectric stations and their associated energy-intensive industries throughout

Siberia, providing the necessary infrastructure, and then interconnecting them with a good transportation network can lead to expansion of Siberia's resource base and also provide the necessary raw materials to supply the Soviet industrial core. The diffusion of industry, especially the extractive and energy-intensive types, in Siberia will lessen the strains of resource development in the European sector of the USSR. The Siberian development nodes will also provide for the refining and initial processing of raw materials at their sources. This method will provide the Soviet Union access to extensive mineral and energy resources at a low cost in terms of labor and Siberian infrastructure investments. The initial processing or refining of resources at their point of origin will provide savings on transportation costs and permit more efficient use of the transportation facilities without undue overloading of the networks through hauling non-economic loads.

Soviet Economic Plans

The Tenth Five-year Plan and the guidelines for the Fifteen-year Plan (1976-90) reflect the technological changes in Soviet industry and resource development. The construction of the Baikal-Amur Mainline Railroad in zones of intermittent permafrost to increase accessibility to Siberian resources and the integration of Soviet electrical grids at extra-high voltage tension are major examples of

the technological emphasis in these plans. The massive thermal power developments at Ekibastuz and Kansk-Achinsk, being built to provide power to the central industrial base, 3,000 kilometers to the west, was not possible prior to new transmission technology for electric power.

The Tenth Five-year Plan and the guidelines for the Fifteen-year Plan (1976-90) for the development of Siberia could represent a new direction in Soviet development. The Leninist philosophy of equal development throughout the state appears to be in the process of being restructured into the classic core-periphery model of national economics in which the European USSR and the Urals will continue to function as the industrial base, while Siberia, with its vast resources and forbidding environment, will function as the resource periphery.

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Appendix 1

Glossary of Technical Terms

Alternating Current--an electric current that reverses direction at regular intervals, having a magnitude that varies continuously in a sinusoidal manner.

Annual Capacity--the average potential power capacity of a river over the period of a year, or, for a power station, the average operating capacity over a yearly period. To convert average annual capacity to annual output in kilowatt-hours, multiply the rated capacity by 8760, the number of hours in a year.

Direct Current--an electric current of constant direction, having a magnitude that does not vary or varies only slightly.

Head--the vertical height of a column of water from a dammed or flowing source to the hydroturbins in a hydroelectric station.

Hydroelectric station--an electric power station generating electricity from water power sources.

Installed Capacity--the total of the rated electric power capacities of all generators in an electric power station, or, for a power system, the total of the installed capacities of all stations it encompasses.

Kilovolt--one thousand volts.

Kilowatt--one thousand watts, equivalent to 1.34 horsepower. This is the most common unit used to measure the potential annual power output of rivers and the actual annual power output of hydro and thermal stations.

Peak Power Period--the period or periods of maximum electric power demand on an individual station or power system during one day (24 hours).

Standard Fuel--an energy measure used by Soviet statisticians to provide equivalents in the energy fuel sources in terms of tons of standard fuel (SF), standard fuel being defined as that containing 7,000 calories per kilogram or 7-million calories per metric ton.

Appendix 2

Abbreviations

ac	alternating current
ASSR	Autonomous Soviet Socialist Republic
C	Centigrade temperature scale
dc	direct current
GOELRO	Gosudarstvennaya Kommissiya Elektrifikatsiya Rossii (State Commission for the Electrification of Russia)
HES (GES)	hydroelectric station
kv	kilovolt (1000 volts)
kwhr	kilowatt-hour
MW	megawatt (one million watts)
TES (TET)	thermal electric stations
USSR	Union of Soviet Socialist Republics